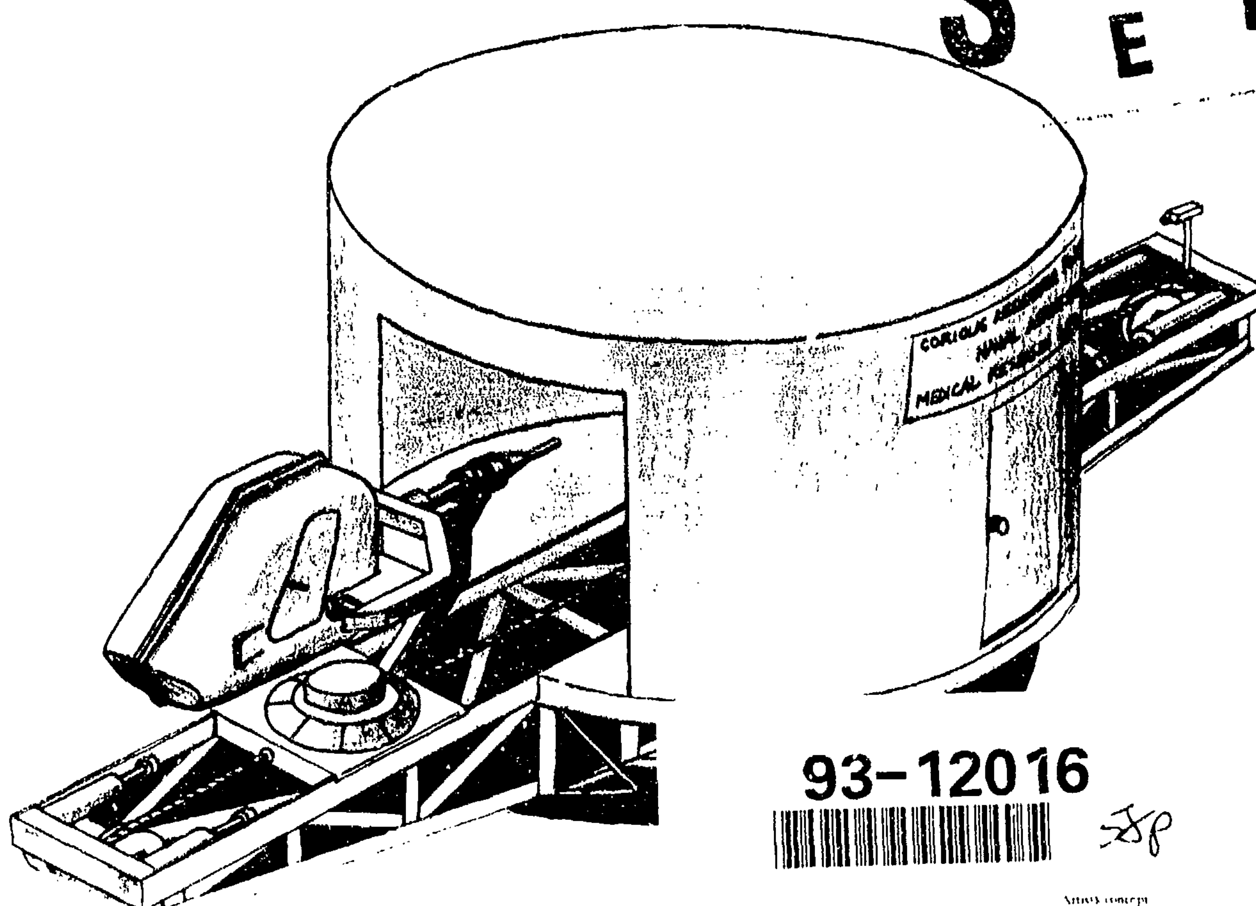
Naval Aerospace Medical Research Laboratory

NAMRL Special Report 93-1

MOTION AND SPATIAL DISORIENTATION SYSTEMS: SPECIAL RESEARCH CAPABILITIES

Edited by A.H. Rupert and R.E. Gadolin



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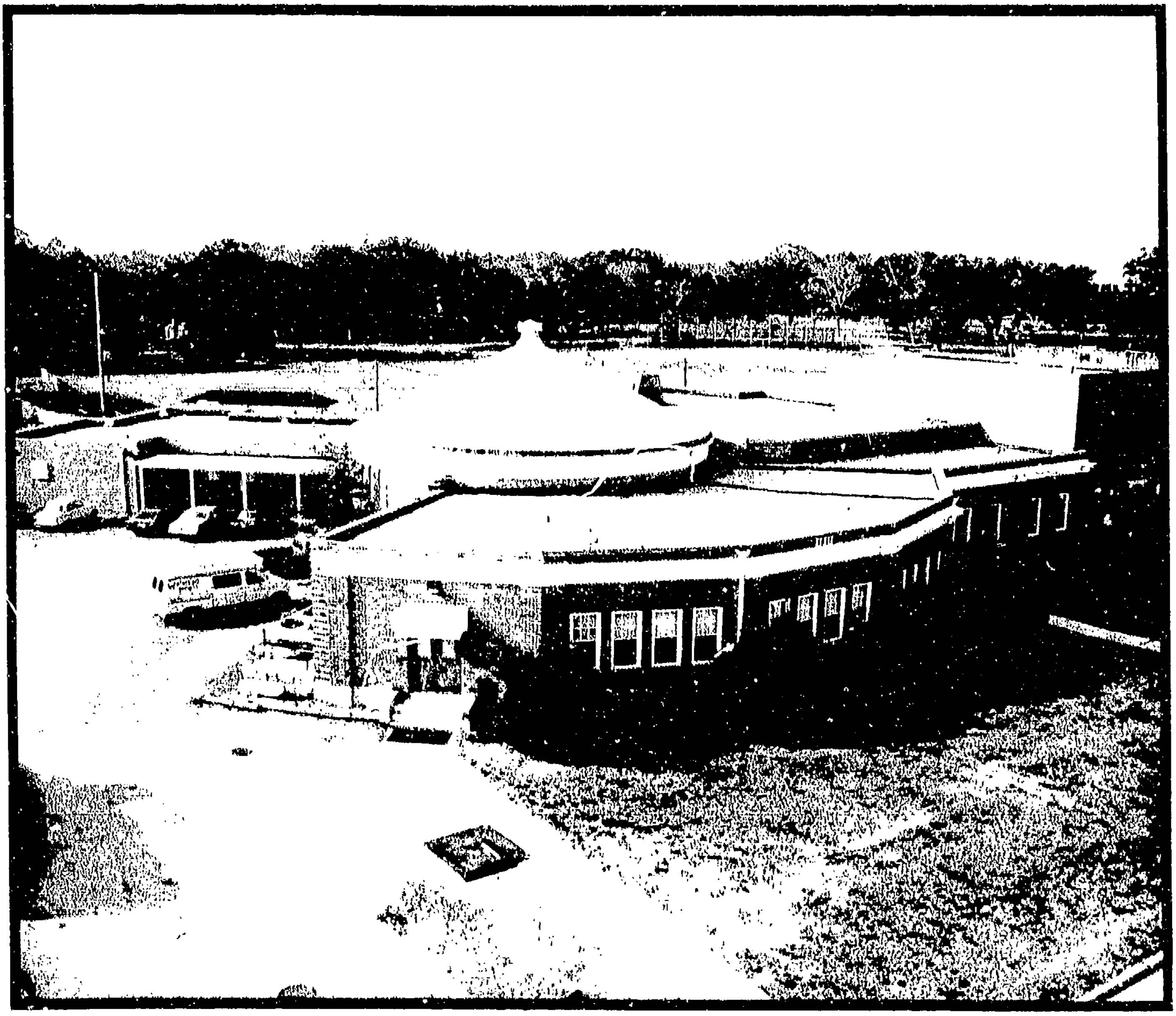


INTRODUCTION

The varied missions of the United States Navy require that sailors and marines venture into a variety of motion-based environments that adversely affect human performance. Currently, the two most significant problem areas created by unusual acceleration environments are spatial disorientation (SD) and motion sickness (MS).

Spatial disorientation for aviators is the incorrect perception of attitude, altitude, or motion of one's own aircraft relative to the Earth or other significant objects. Spatial disorientation costs the United States Navy in excess of 100 million dollars per year in lost aircraft in addition to the loss of approximately 10 aircrew per year. The other branches of the DoD (USAF and US Army) experienced material and personnel losses of a similar magnitude.

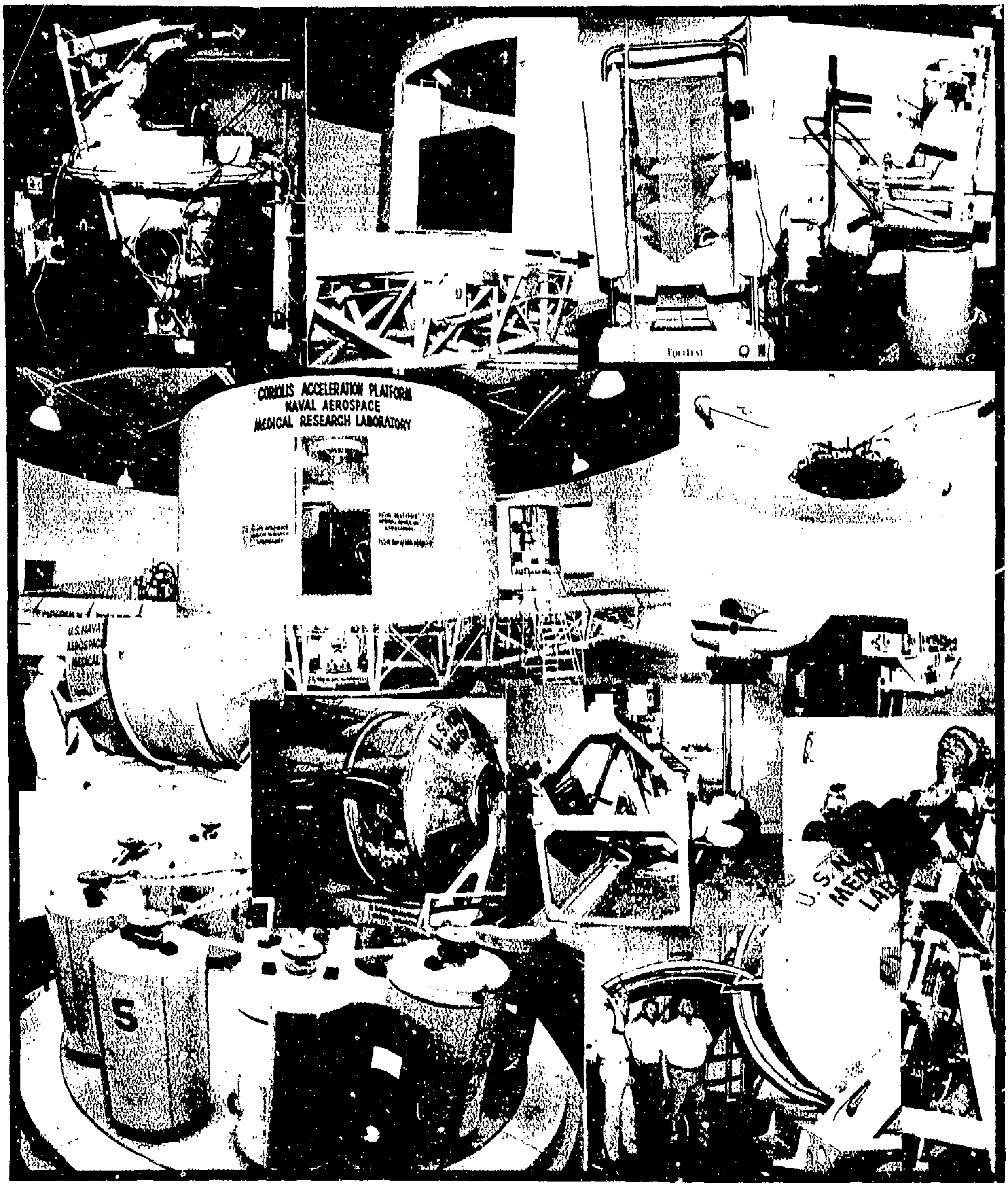
Motion sickness is a maladaptive response to real or apparent motion that has debilitated sailors and troops being transported to landing sites since the first ship sailed. We include "apparent motion" in our definition to address the closely related phenomenon of simulator sickness, which is becoming an evermore significant problem as the military and civilian communities increase reliance on simulators for training.

The sensory systems involved in the phenomenon of spatial disorientation and motion sickness are the visual, vestibular, and somatosensory systems. The vestibular system is the *only* sensory system devoted exclusively to the detection of acceleration. Secondary information is supplied by vision and somatosensory information from skin, muscle, and joint. The pivotal role played by the vestibular system is evidenced by the *absolute* immunity to motion sickness in individuals with nonfunctioning vestibular end organs. All other individuals are susceptible to motion sickness.

The National Aeronautics and Space Administration (NASA) also has a strong interest in the problems of motion sickness (80% of astronauts experience space motion sickness) and spatial disorientation (disorientation during and after transition between Earth and space acceleration environments frequently results in motor incoordination). For these reasons, the United States Navy, with generous support and cooperation from NASA, has for the past 30 years designed, developed, and assembled the world's best collection of man-rated acceleration devices to explore the modus operandi of the inner ear and its interaction with visual and proprioceptive information. The goal is to understand basic mechanisms so that practical solutions can be developed to solve the operational problems of spatial disorientation and motion sickness.

The wide variety of unique devices together with the scientists and technicians who operate them have enabled the Naval Aerospace Medical Research Laboratory (NAMRL) to develop an international reputation as a center of excellence in vestibular research and the dynamics of spatial orientation. It has also become an international resource for training scientists engaged in basic research.

This document contains a brief description of the man-rated acceleration research facilities of the United States Navy.


CORIOLIS ACCELERATION PLATFORM
NAVAL AEROSPACE
MEDICAL RESEARCH LABORATORY
U.S. NAVAL
AEROSPACE
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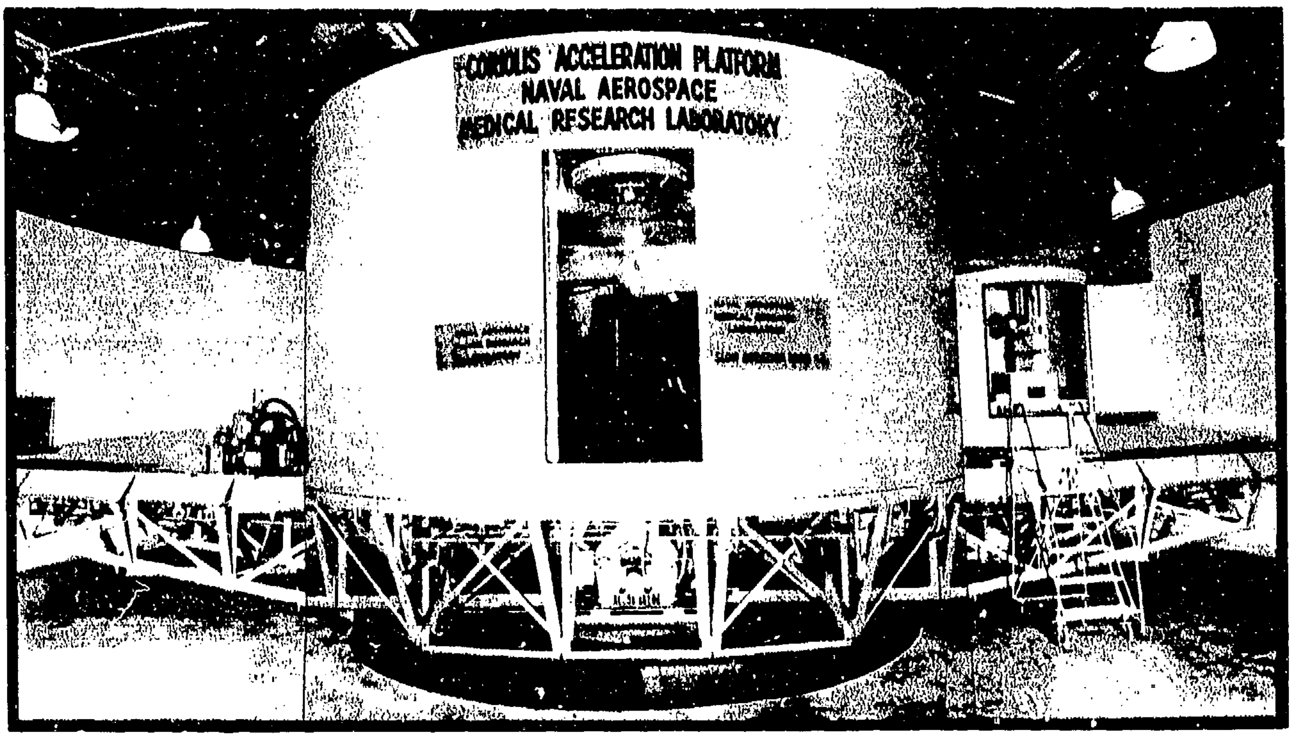
ACCELERATION DEVICES

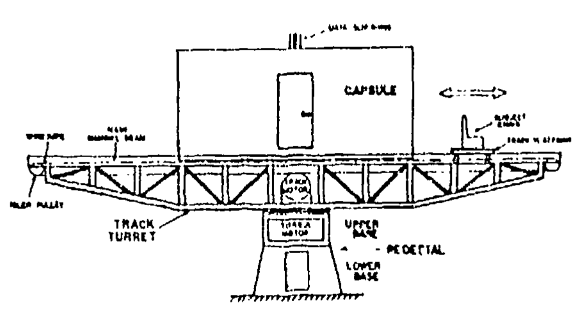

CORIOLIS ACCELERATION PLATFORM
NAVAL AEROSPACE
MEDICAL RESEARCH LABORATORY

CORIOLIS ACCELERATION PLATFORM

ROTATING CAPSULE

The Coriolis Acceleration Platform (CAP) has the capability of applying combined linear and angular acceleration to the human subject*. It is the only device in the DOD inventory available to study chronic exposure to altered G environments. The maximum rated velocity of the device is 200 deg/s (33 rpm) with a maximum angular acceleration of 15 deg/s^2. Unbalanced loads weighing up to 1500 pounds can be installed inside the capsule (for example, the Life Support Module consisting of kitchen appliances, floor and upright storage cabinets, and a shower) if the maximum angular velocity is limited to 120 deg/s (20 rpm) or less. The device is capable of generating repeated or periodic accelerations; the duty cycle at 15 deg/s^2 is 10 min out of every hour thereby permitting 37 ramp up/down profiles per hour. With combined linear angular motions, the stimulus profiles must be selected so as to never exceed ±3 G in the horizontal plane when the track platform is in operation.

When subjects are in fixed position at the maximum radius of 20 ft, centripetal acceleration up to 7.45 G-units can be produced.



ELEVATION

TRACK PLATFORM

The normal operating limits are ±18 ft displacement, ±16 ft/s maximum velocity, ±2 G maximum linear acceleration. The maximum payload at 2 G is 750 pounds. For brief intervals (less than 5 min), the peak acceleration may be raised to ±3 g.

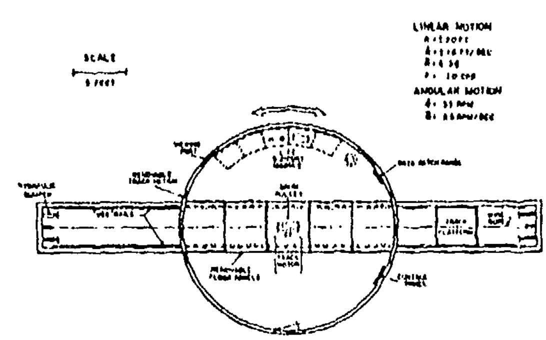
COUNTER-ROTATOR (CORO)

The CORO permits rotation about an axis parallel to the main axis of the CAP. The maximum operating limits for CORO counter-rotation aboard the capsule include a maximum velocity of 100 deg/s, a maximum angular acceleration of 15 deg/s^2, and a maximum centripetal acceleration exposure of CORO to 1.75 g. The CORO can be driven along the track up to a radius of 18.5 ft.

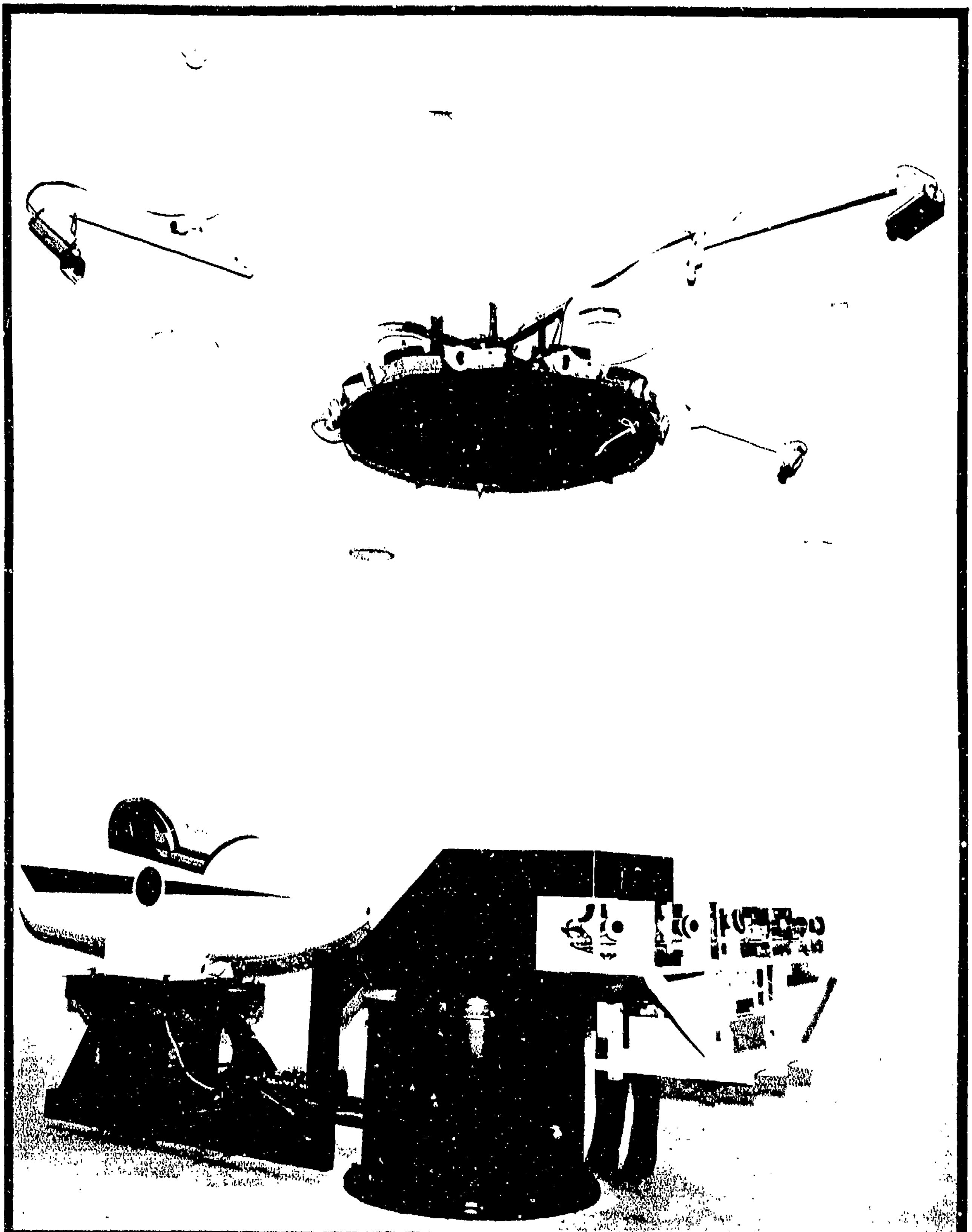
OTHER

Many forms of combined CAP motion, track motion, and CORO motion provide unique capability, for example, subjects can be moved along the track in and out of G-fields produced by CAP rotation.

*See references 3, 4, 7.



PLAN



DYNASIM

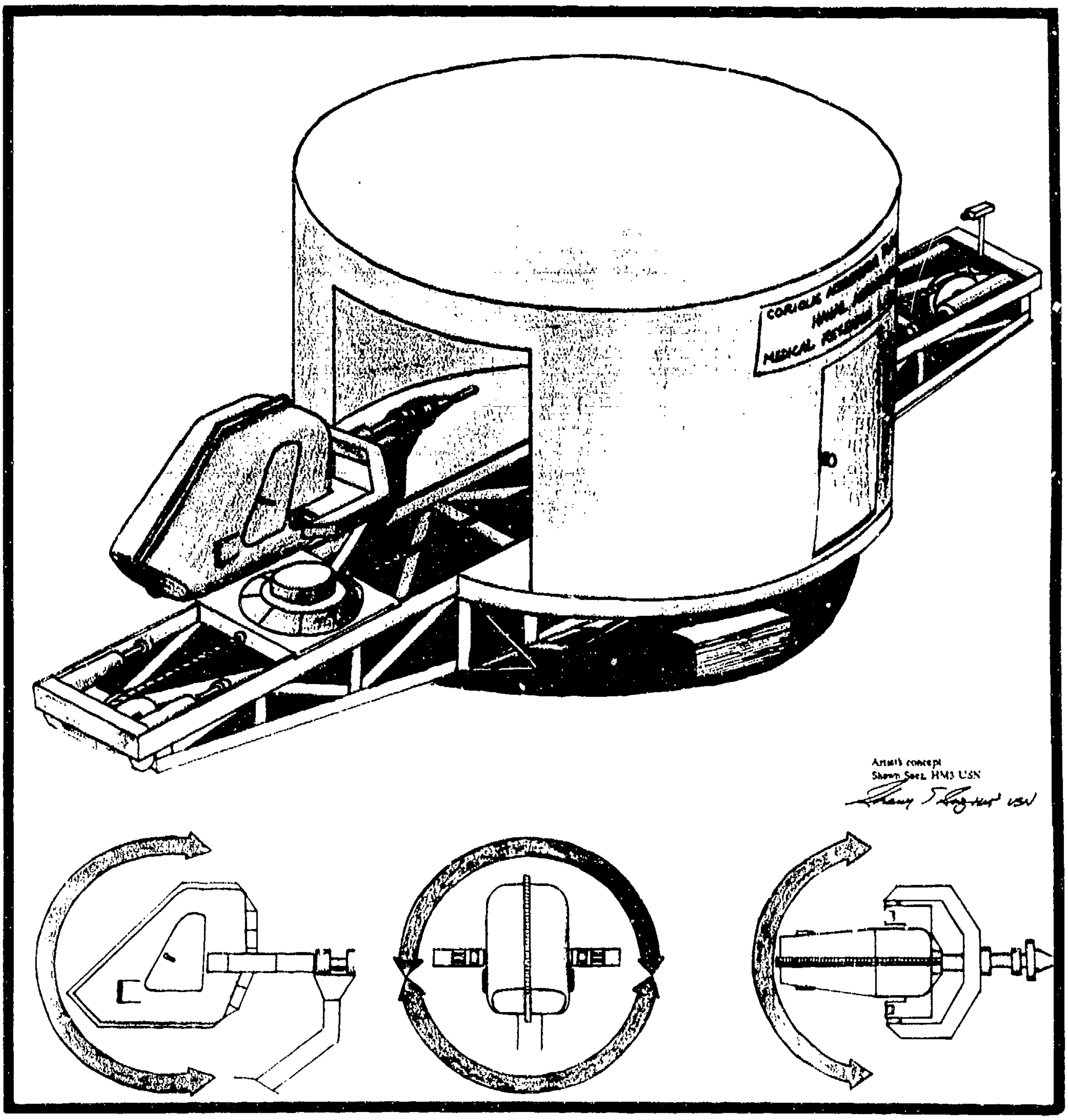
The Dynasim is a three-degrees-of-freedom servo-controlled rotating device*. The main element of the Dynasim is a cockpit assembly that simulates an aircraft in appearance. The cockpit assembly is installed on a steel-radial arm structure that in turn is bearing supported on a drive pedestal centered in a large circular room approximately 50 ft in diameter. Rotation of the cockpit assembly results in the generation of low-level centripetal linear acceleration stimuli combined with low-level angular acceleration stimuli during changes in angular velocity. The device has the capability of rotating the cockpit assembly at a maximum angular velocity of 150 deg/s (25 rpm) and a maximum angular acceleration of 20 deg/s^2.

The device also provides two additional degrees of freedom in the form of pitch-and-roll motions of the cockpit assembly relative to Earth vertical. Hydraulic actuators, controlled by either the operator or subject, allow cockpit displacements to be ±30 deg from vertical along either the pitch or roll axes with a maximum rate of 30 deg/s. The cockpit assembly can also be rotated manually and locked into one of four different quadrant positions to allow for different subject orientation relative to the rotational center.

A unique feature of the NAMRL installation involves provisions for projection of fixed or moving visual images on the chamber wall. The walls of the chamber have been specially prepared for the overhead projection of different visual patterns and scenes that will be viewed by the subject in selected experimental situations through a clear cockpit canopy. The chamber will, in general, be kept in complete darkness under those experimental conditions requiring intermittent exposure to the visual stimuli projected on the chamber walls.

The cockpit assembly contains a removable instrument panel with selected subject indicators and control instruments that are generally custom designed according to specific research requirements. A Malcom Horizon, a peripheral vision horizon device, is also available.

*See references 8, 10.


CORIOLIS
NAVAL
MEDICAL
Artist's concept
Shawn Seez, HM3 USN

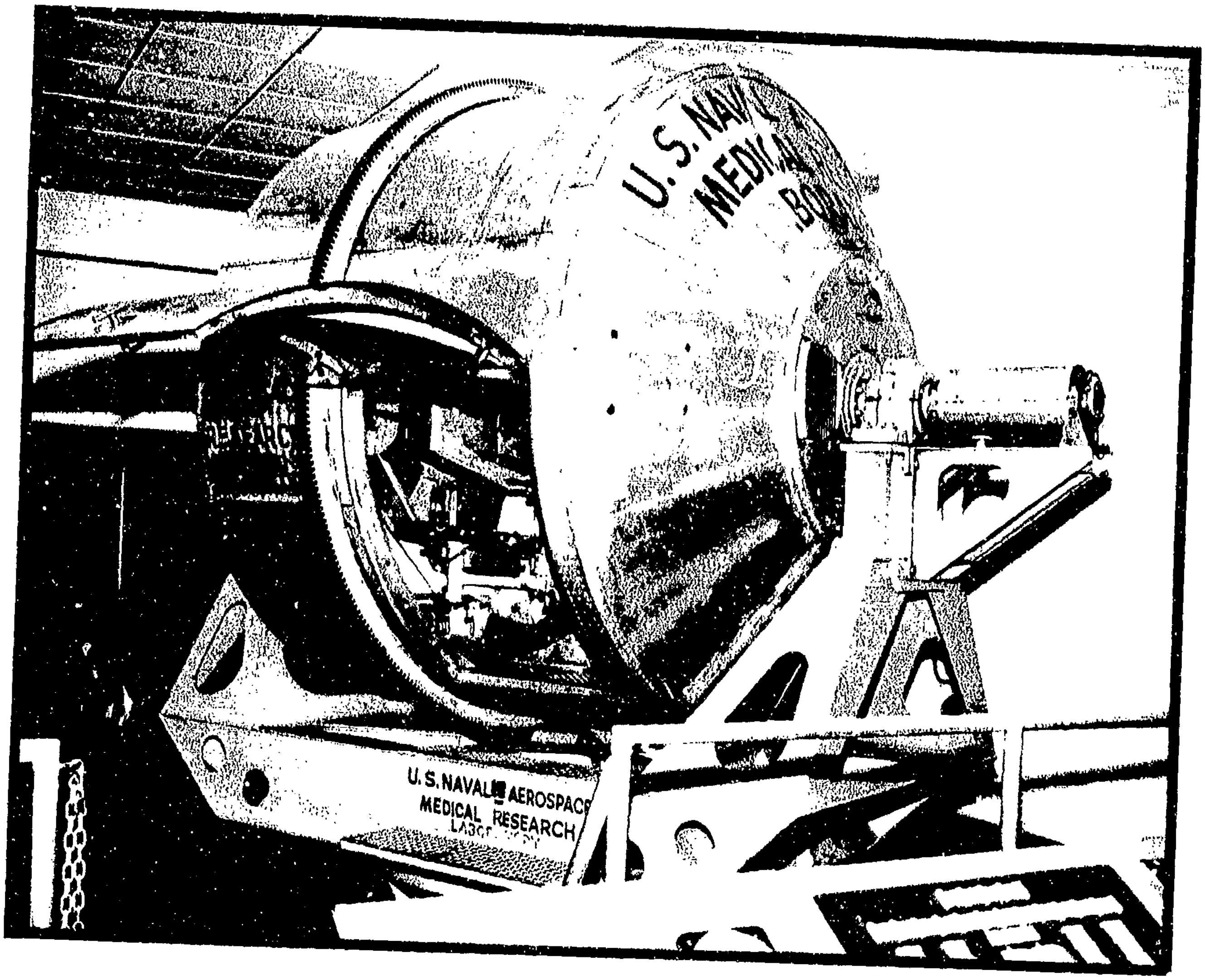
SIM III

The first generation of motion-based aircraft simulators had limited motion in roll, pitch and yaw, and a few feet of linear translation. Due to the limited linear translation, pilots could be exposed to acceleration for only a fraction of a second. To overcome this inadequacy, the more recent second-generation devices (e.g., Dynasim, page 9) include rotation about a planetary axis so that the pilot can experience continuous gravitoinertial forces. Neither generation gives realistic perceptions of motion. Our considerable experiences with negative transfer of training associated with the second-generation devices led our engineering staff to design and build the third-generation device SIM III, which overcomes the earlier deficiencies by adding the capability of linear motion in and out of a gravitoinertial force field. This has been accomplished by mounting a closed-loop control device (roll, pitch, and yaw) on the coriolis acceleration platform (page 5).

On completion, this device will be the *ultimate* motion-based simulator platform available as a research tool to investigate the basic mechanisms of spatial orientation. The information obtained from basic studies will be used to design new orientation instruments and tests to improve biomedical readiness. Improved instruments will be evaluated on this latest generation simulator.

Specifications

Roll ±90 deg
Pitch ±90 deg
Yaw unlimited
Peak G exposure ±3 G
The linear translation specifications are the same as those of the track on the coriolis acceleration platform (page 5).


U.S. NAVAL AEROSPACE
MEDICAL RESEARCH

HUMAN DISORIENTATION DEVICE

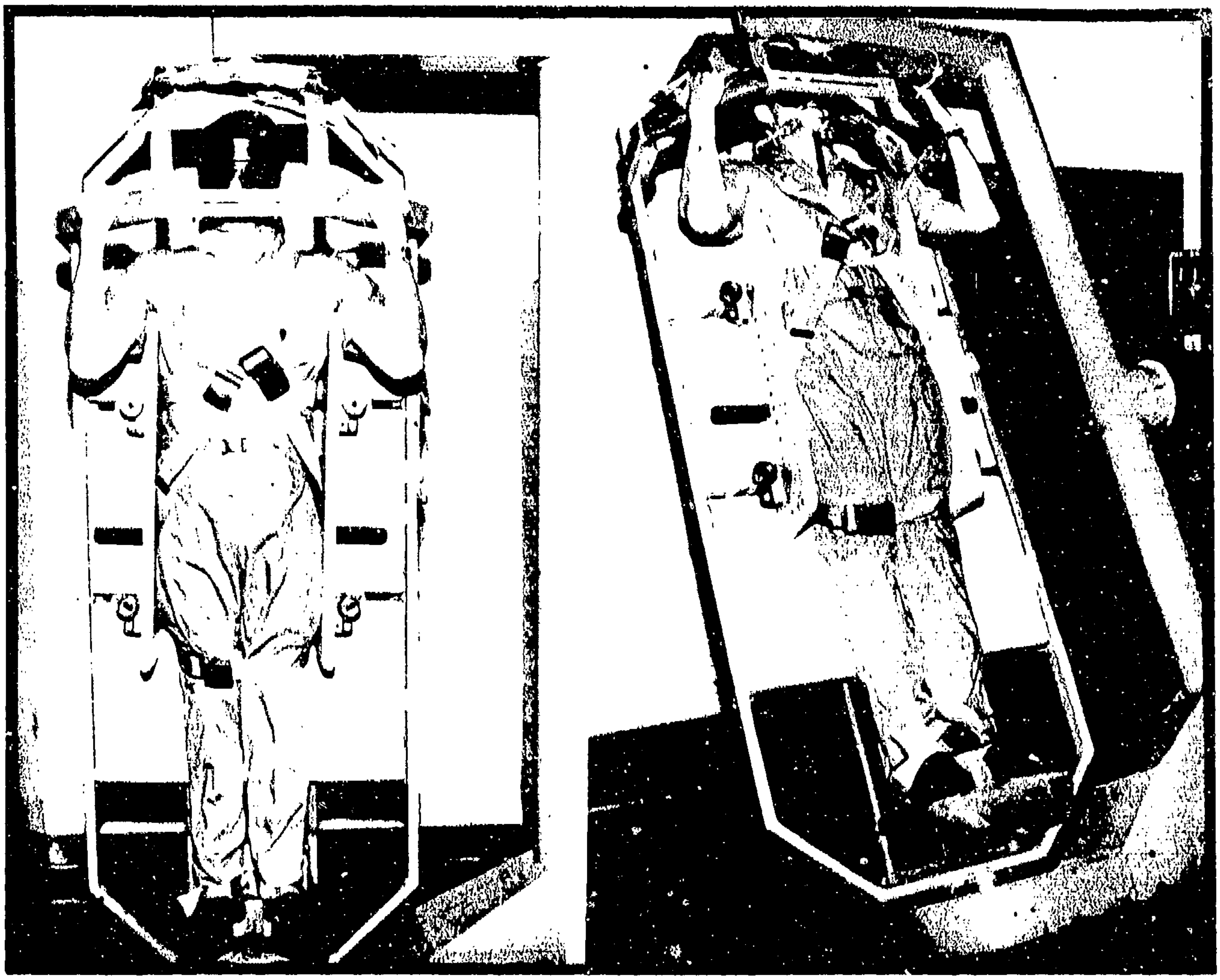
The Human Disorientation Device (HDD) is unique in that it is capable of accelerating an instrumented human subject about two head-centered axes simultaneously*. Such a tool is indispensable to help differentiate the relative roles played by the various sensory systems involved in the production of disorientation as well as to examine the contribution of each system and subsystems to motion sickness.

The HDD was designed to permit rotation about both an Earth-vertical or Earth-horizontal axis, either singly or in combination. Maximum ratings for each axis include a peak velocity of 60 rpm (360 deg/s) and a peak angular acceleration of 300 deg/s^2. The device is designed for either position or velocity feedback closed-loop control of each axis.

When the device is properly balanced, the payload for rotation about Earth-vertical is approximately 3100 pounds. For simultaneous rotation about both axes, the total payload must be reduced to 2100 pounds.

For sinusoidal rotation, the device has a maximum upper frequency rating of 0.2 Hz with the maximum peak angular acceleration limited to 100 deg/s^2. The device may be oscillated at lower frequencies with the condition that the peak angular velocity can never exceed 180 deg/s and the peak angular acceleration can never exceed 100 deg/s^2.

*See references 1, 9.

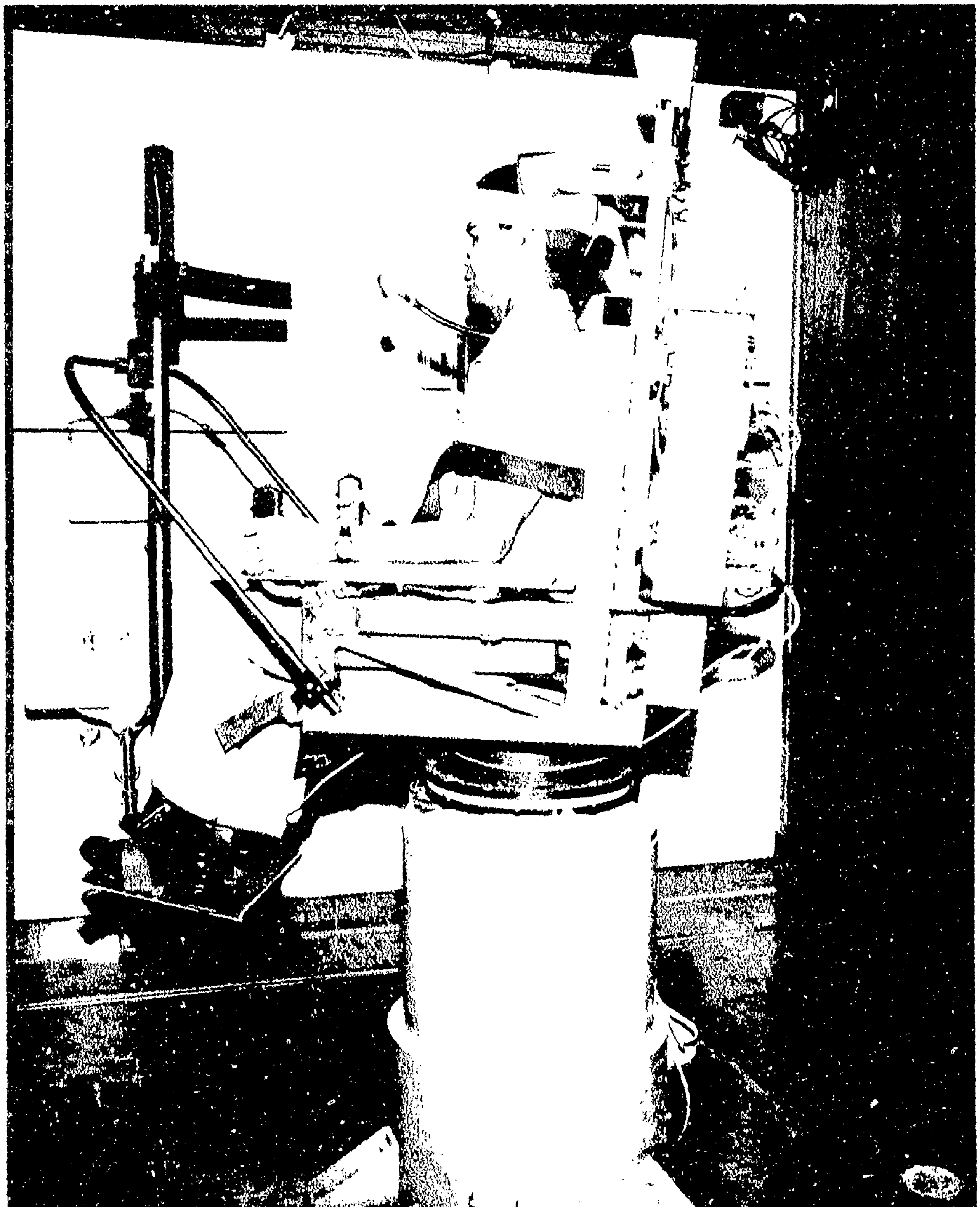


VARIABLE-POSITION LITTER DEVICE

The variable-position litter device consists of two independently rotating frames, each driven by a 1/3 HP dc motor, which may be rotated simultaneously or singly. The axis about which the outer frame rotates produces head-over-heels rotation of human subjects. The inner frame is pivoted to the outer frame and permits rotation about the cranio-caudal axis. The subject is strapped to the inner frame. Angular accelerations and final angular velocity can be preset for either frame by dials on the control panel. The maximum constant angular velocity and constant angular acceleration of the inner frame are 120 deg/s and 26 deg/s^2, respectively. Maximum angular velocities and accelerations of the outer frame are 18 deg/s and 6 deg/s^2, but this frame is used mainly for positioning the subject relative to gravity.

Slip rings from the inner to the outer frame and another set from the outer frame to the support permit recording of corneo-retinal potentials and other response variables.

Subjects are secured to a padded bed on the inner frame by a headrest and adjustable side pieces and footrest, and safety straps across the feet, thighs, chest, shoulders, and head.

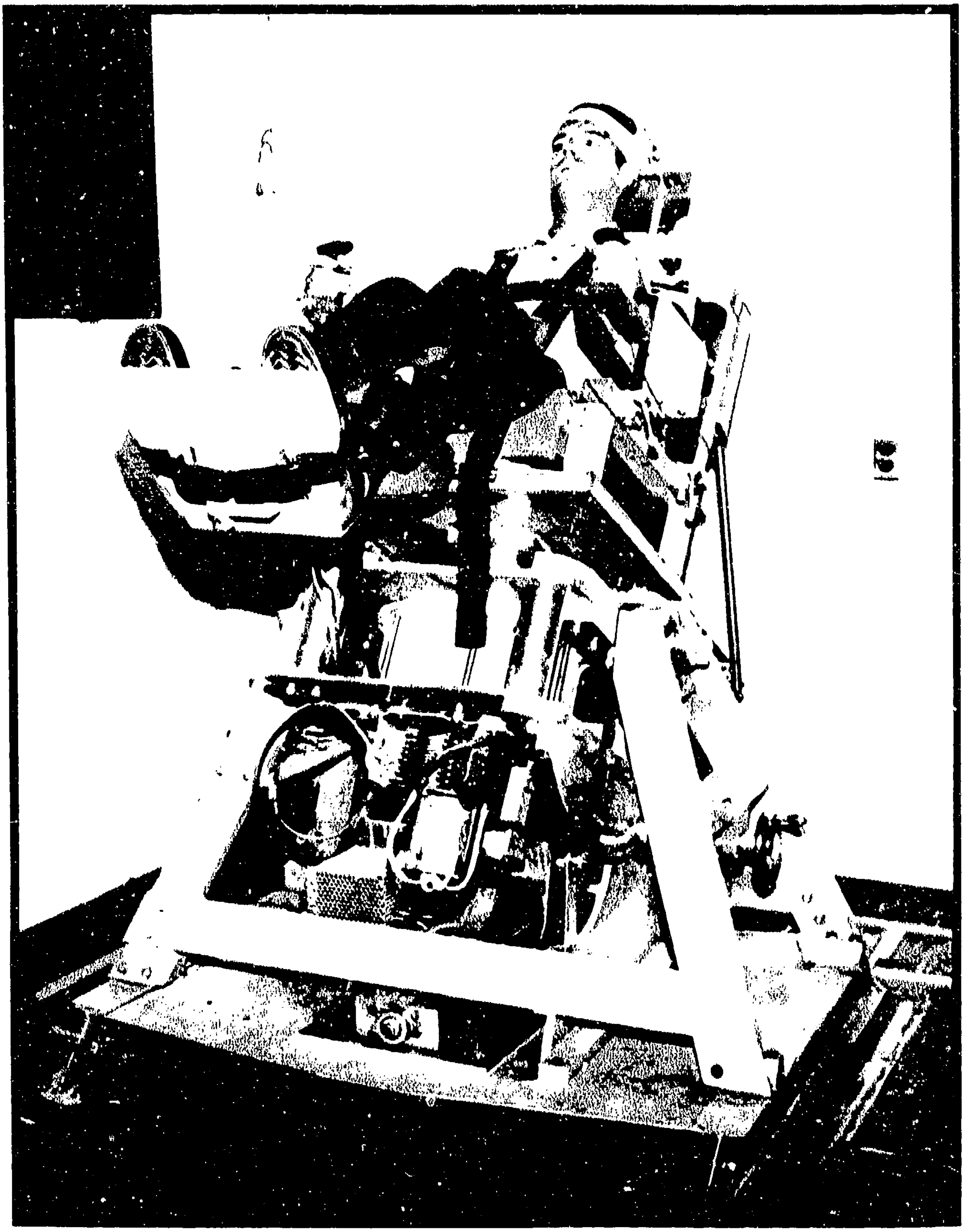


PERIODIC ANGULAR ROTATOR (PAR)

The Periodic Angular Rotator (PAR), is a high-performance man-rated motion device that rotates a seated subject about the Earth-vertical axis*. A low-speed, direct-coupled, dc torque motor is operated as either a velocity or displacement mode power servomechanism to achieve a drive system with low acoustic noise and mechanical vibration characteristics, fast dynamic response performance, and a high degree of coupling stiffness.

The device has a maximum angular velocity of 600 deg/s (100 rpm), a maximum angular acceleration of 100 deg/s^2, and can be programmed to produce sinusoidal angular acceleration stimuli extending to 2.0 Hz. The device will respond to high frequency command signals but the acceleration waveform will be distorted.

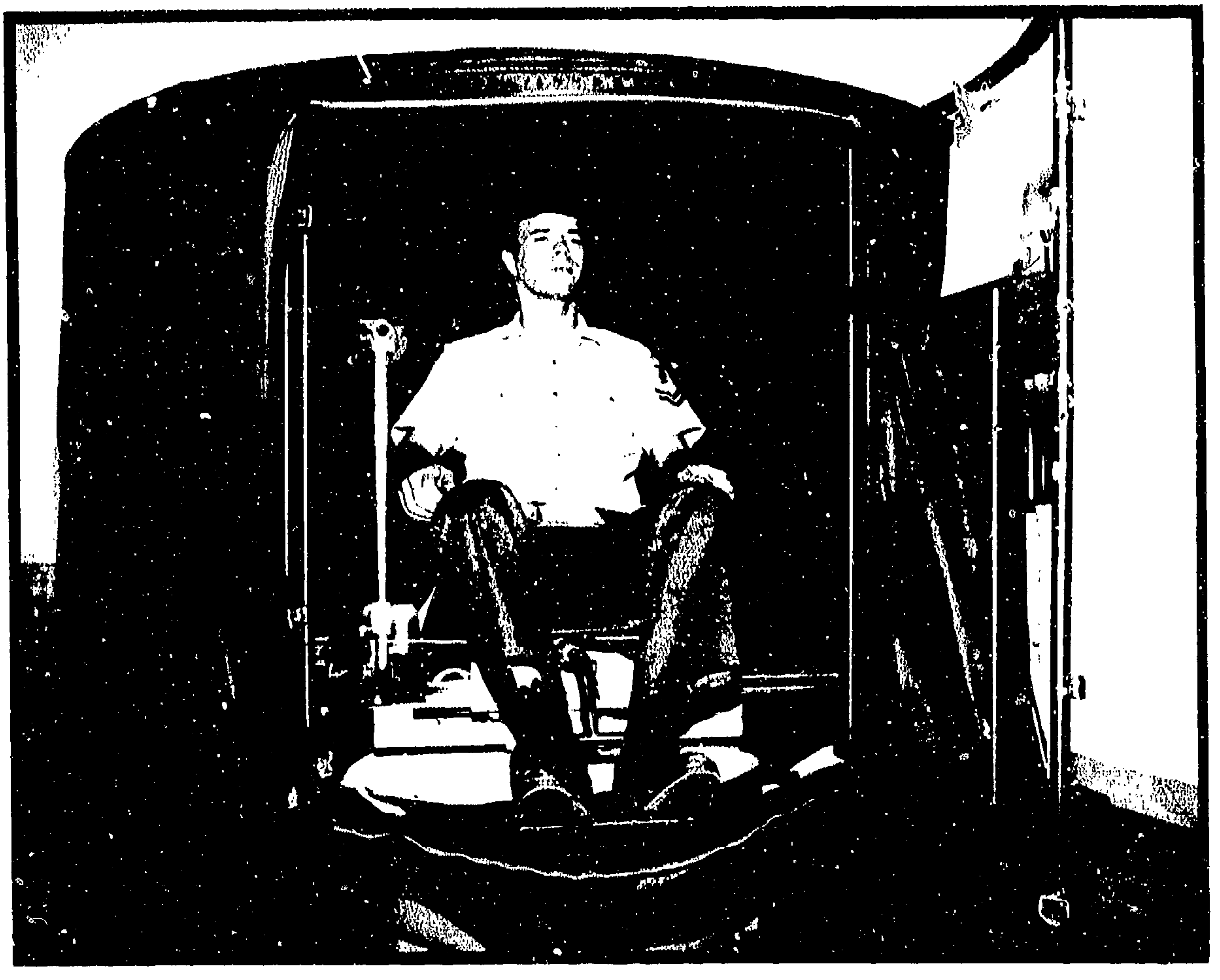
*See references 2, 5.



OFF-VERTICAL ROTATOR (OVR)

The function of the OVR is to operate at constant angular velocity at different tilt angles relative to Earth vertical*. The tilt angle is adjustable over the 0-30 deg range. The maximum allowable chair velocity is 50 rpm for tilts between 0 and 15 deg, and 30 rpm for tilts beyond the 15 deg. Design of the chair servo-drive system was keyed to providing good low-frequency response so as to counteract the disturbing torques introduced by tilted axis rotation. A counter-weight mechanism located behind the chair proper has been provided to give a limited amount of static balancing to allow for individual variations in subject mass/inertia distribution. The objective of the static balancing assembly is to minimize variations in chair velocity that occur cyclically according to the position of the chair rotation axis relative to vertical. Because the servo system was designed to minimize these low-frequency cyclic variations in velocity, the basic operating characteristics are not suitable for periodic or high-onset velocity profiles that involve high-frequency performance requirements.

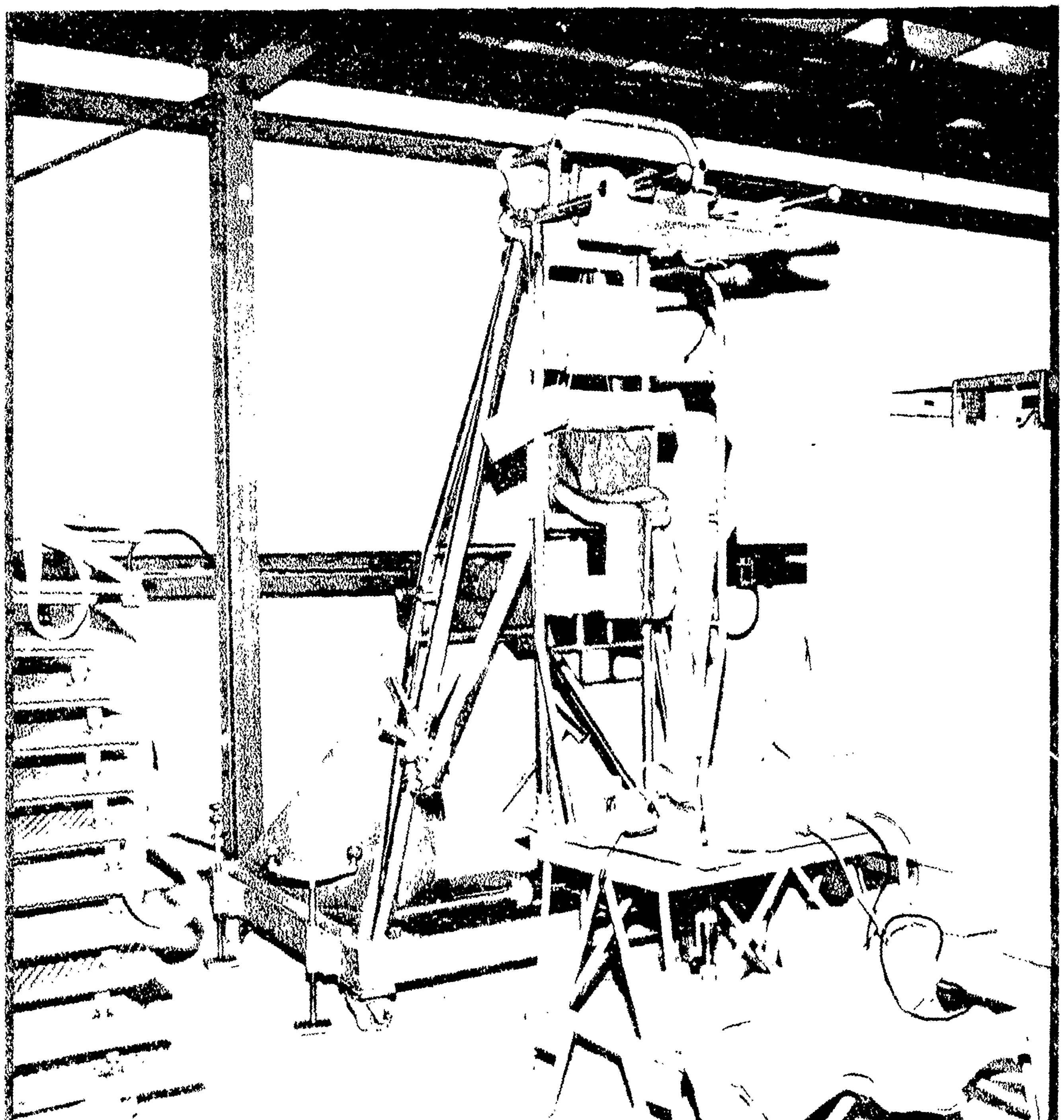
*See reference 6.



STILLE-WERNER CHAIR

The Stille-Werner RS-3 rotating chair was designed for clinical investigation of vestibular reactions during stimulation of the horizontal semicircular canals. The RS-3 has a maximum angular velocity of 200 deg/s and a peak angular acceleration rate of 15 deg/s^2.

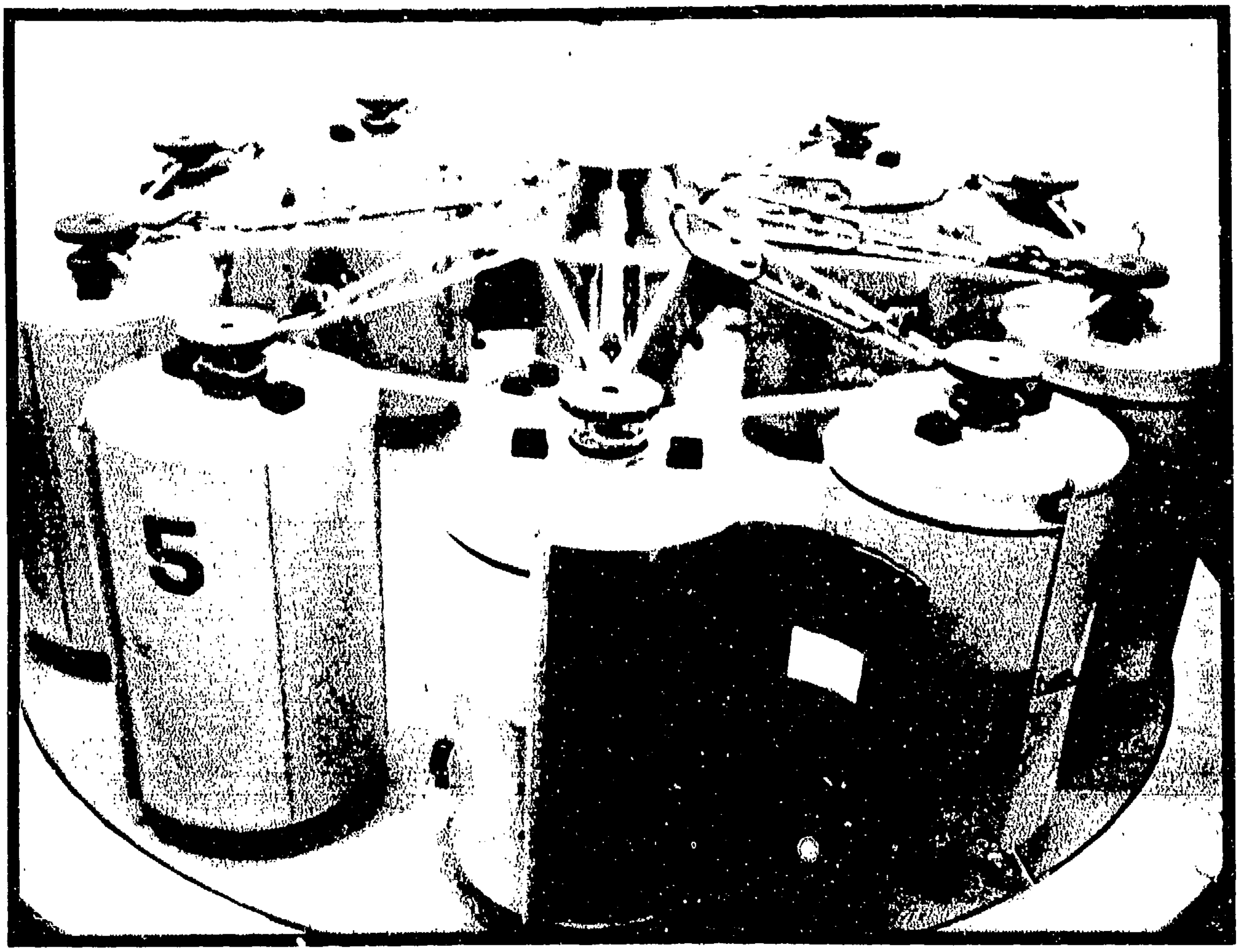
The subject chair can be located up to 2 ft from the center of rotation and is equipped with an efficient slip-ring transmission system for transmitting nystagmus signals. The chair has a removable blackout cover for investigation in total darkness.



OCULAR COUNTERROLL DEVICE (OCR)

The ocular counterroll device (OCR) rotates subjects about the roll axis through the head while simultaneously recording the compensatory roll movement of the eyes in the opposite direction.

The ocular counterroll device is used as a means to investigate otolith function. This device will be returned in January 1994 to the Naval Aerospace Medical Research Laboratory from a long-term loan to the Massachusetts Institute of Technology (MIT). It is currently being reconfigured by MIT to deliver varied roll rates to examine the dynamic aspects of ocular counterroll.


5

MULTISTATION DISORIENTATION DEMONSTRATOR

The Multistation Disorientation Demonstrator (MSDD) provides disorientation familiarization training for student pilots, student flight officers, student flight surgeons, aviation psychologists, and physiologists. This training augments classroom lectures by giving students a memorable personal experience that spatial disorientation is a normal response to a variety of conditions.

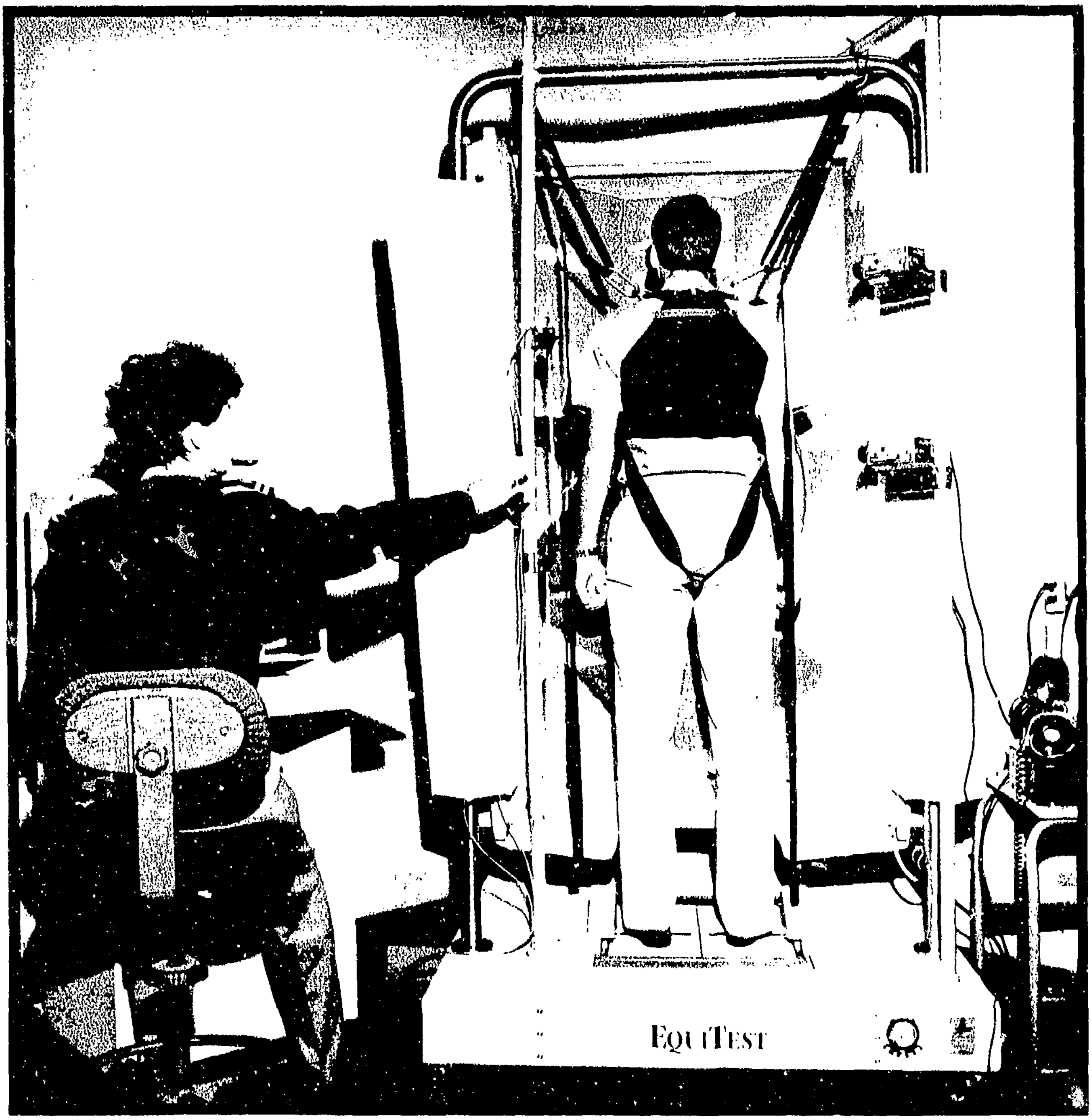
The MSDD enables students to experience spatial disorientation errors caused by the loss of reliable points of reference, conflicting sensory cues, and elevated inertial forces. When the capsule doors are closed and locked, external aural cues become negligible, and student access to visual cues is controlled by the instructor/operator. If the capsule aperture shutter is closed, a student's field of vision is limited to the capsule interior; but when opened, the student may observe a projected image on a 12-ft high circular screen (circular surround) that encompasses the platform. The image seen by the student may be an artificial horizon offset from true horizontal or merely simple geometric patters. In either case, such a visual cue provides an apparent frame of reference that may conflict with inertial forces experienced by the student. The rotation of the platform, which creates the inertial forces, can be elevated sufficiently to markedly degrade the student's ability to determine true horizontal or perform tasks requiring eye-hand coordination. The MSDD is capable of subjecting the student to a great variety of controlled stimuli by changing capsule orientation during platform rotation, by rotating the platform and projector at different rates, or by requiring the student to respond to instructor commands. Each combination of stimuli results in a distinctive class of disorientation errors similar to experiences that may be encountered during flight.

The MSDD holds 10 student capsules on a rotating platform. A digital computer system controls and monitors all phases of operation.

The MSDD motion capabilities are as follows:

- Maximum angular velocity of the rotating platform is 120 (± 1.0) deg/s (20 rpm) clockwise or counterwise.
- Maximum angular acceleration/ deceleration of the rotating platform is 15 deg/s/s.
- The rotating platform can accommodate from 1 to 10 students.
- The student capsules can rotate 180 deg clockwise or counterclockwise in 90- or 180-deg increments from the radially outboard position.
- The projector assembly provides a choice of seven display patterns on a single acrylic tube. The rotation parameters of the projector assembly are identical to those of the rotating platform.

The MSDD is a training device under the control of another command, the Naval Aerospace and Operational Medical Institute (NAMI), but it is available for special research projects on a noninterference basis. The hydrostatic bearings and closed-loop control of the main structure provide excellent motion-control characteristics.

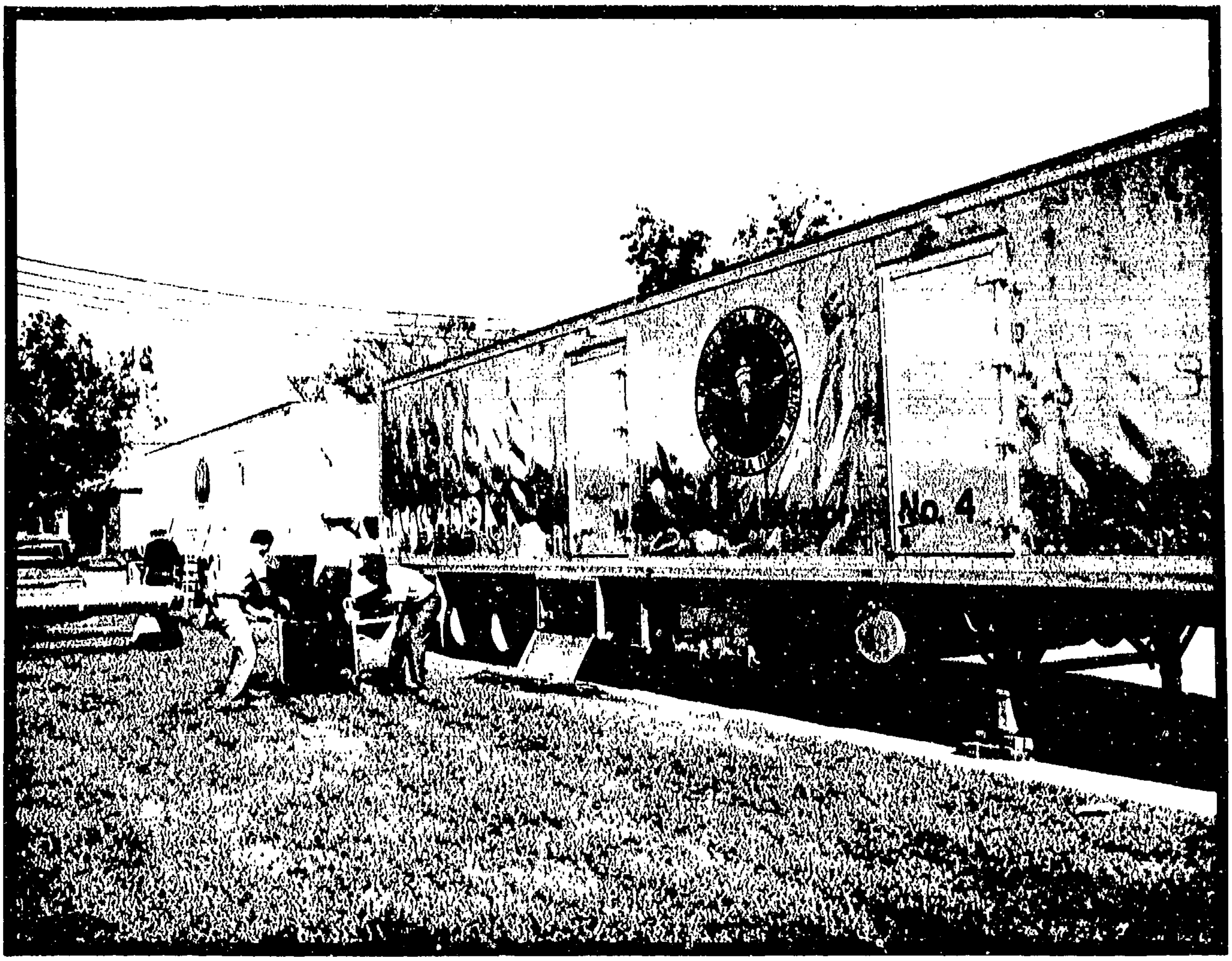

EQUITEST

EQUITEST® SYSTEM

The Equitest System employs computerized dynamic posturography to systematically examine the effectiveness of visual, vestibular, and somatosensory inputs to balance and the timing, strength, and coordination of postural movements. The device is manufactured by NeuroCom International, Inc.

The system contains a dual forceplate capable of measuring a subject's center of gravity, and can rapidly move forward, backward, or tilt. Hermetically sealed temperature-compensated load cells in the forceplate generate output during either static or dynamic tests. A visual surround accompanies the system and can also tilt. Motions of both the visual surface and the forceplate are accomplished with servomotors. Specially engineered software executes test protocols, and analyzes the subject's response and displays test results.

During sensory organization tests, the forceplate and visual surround can be either fixed or sway-referenced. During sway-referencing, the subject is exposed to 20-s trials of inputs in differing combinations that allow for evaluation of visual, vestibular and somatosensory contributions to equilibrium. A series of motor coordination tests include exposure to brief horizontal forward and backward translations of the forceplate. Velocity and amplitude are increased over three sets of five trials, with perturbation sizes adjusted in relation to subject height. Movement response is measured in terms of symmetry, latency, amplitude scaling, strategy, and adaptation.

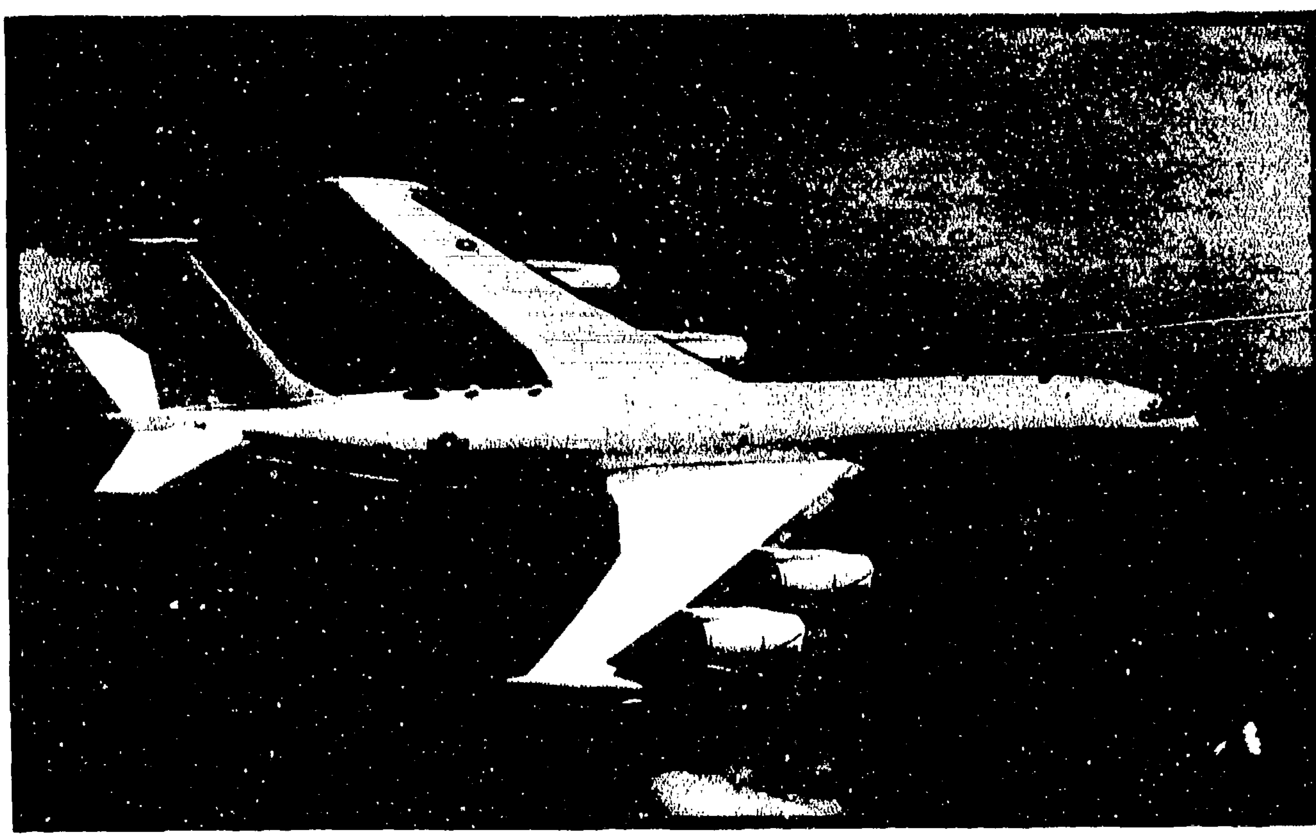

No. 4

MOBILE FIELD LABORATORY

The Naval Aerospace Medical Research Laboratory has completed the design, development, and construction of three new Mobile Field Laboratories (MFLs) for the collection of biomedical performance data at various CONUS military installations. One MFL is devoted to the acquisition of cardiopulmonary data, a second to vestibular data, and a third to the combined acquisition of acoustic and cognitive performance data*. Each MFL, outfitted with its own diesel-driven power source, air conditioning system, and water service, is designed to operate under stand-alone conditions without the need for any form of shore-based support.

The physical layout of the Vestibular MFLs can be visualized as having five different functional regions. An Off-Vertical-Rotating (OVR) chair with uniform surrounds of optokinetic stimulation is installed at the rear of the VMFL within a double-insulated acoustic room; the adjacent room houses equipment for measuring both caloric and ataxia (postural equilibrium) responses. At the very front of the VMFL, a second double-insulated acoustic room houses equipment related to a performance-based test of gaze function as well as selected evoked-response test configurations. The two adjacent rooms contain equipment required to conduct NAMRL-developed tests of Pendular Eye Tracking (PET) capabilities. The fifth region is the centrally located control room, which houses the majority of the bioinstrumentation equipment required to implement these tests.

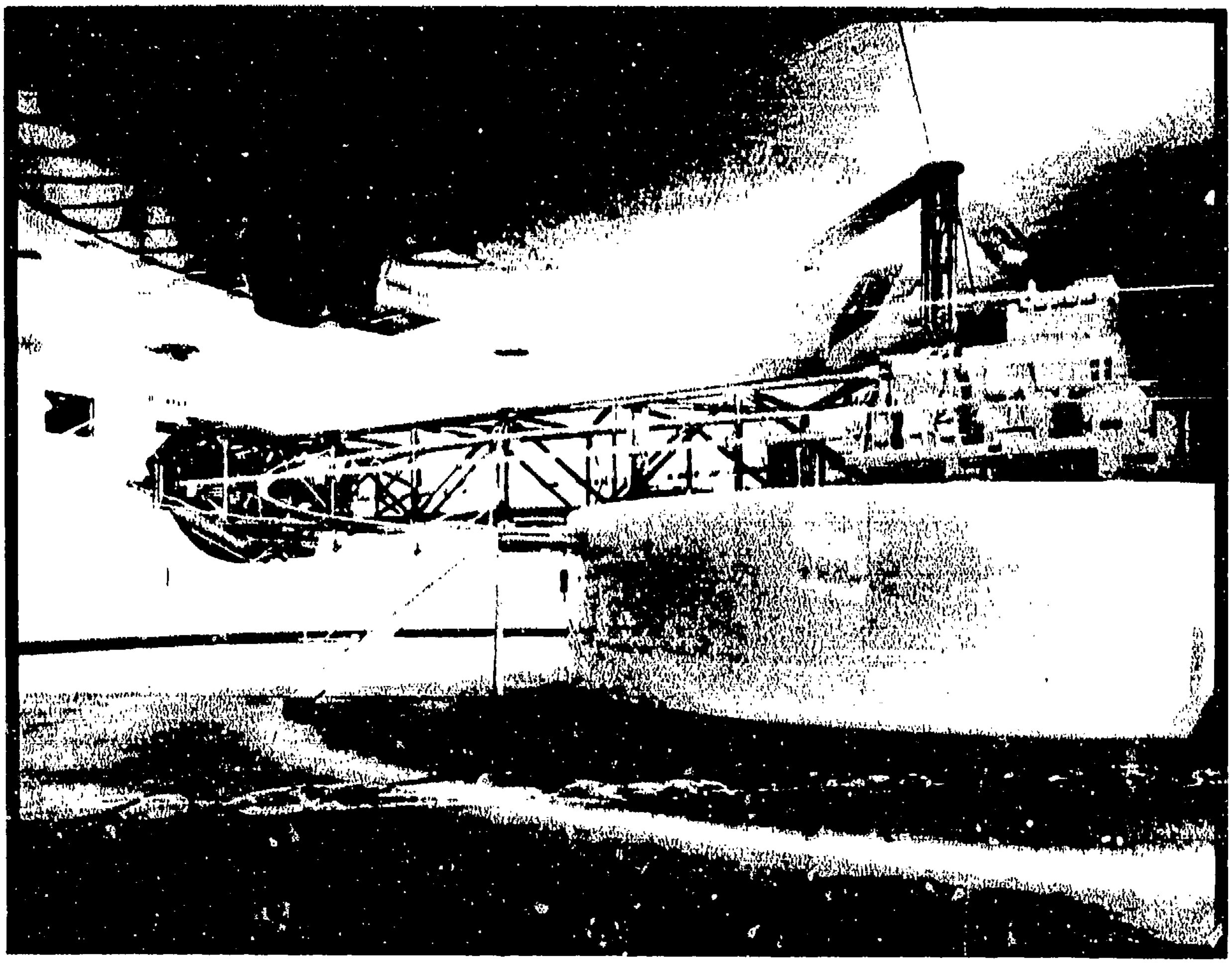
*See reference 10.



AIRCRAFT

The Navy has conducted experiments in cooperation with NASA using the NASA KC-135 aircraft. The Navy TACAMO community has generously agreed to offer support on a "not to interfere" basis for hypergravity research experiments using a modified Boeing 707 aircraft.

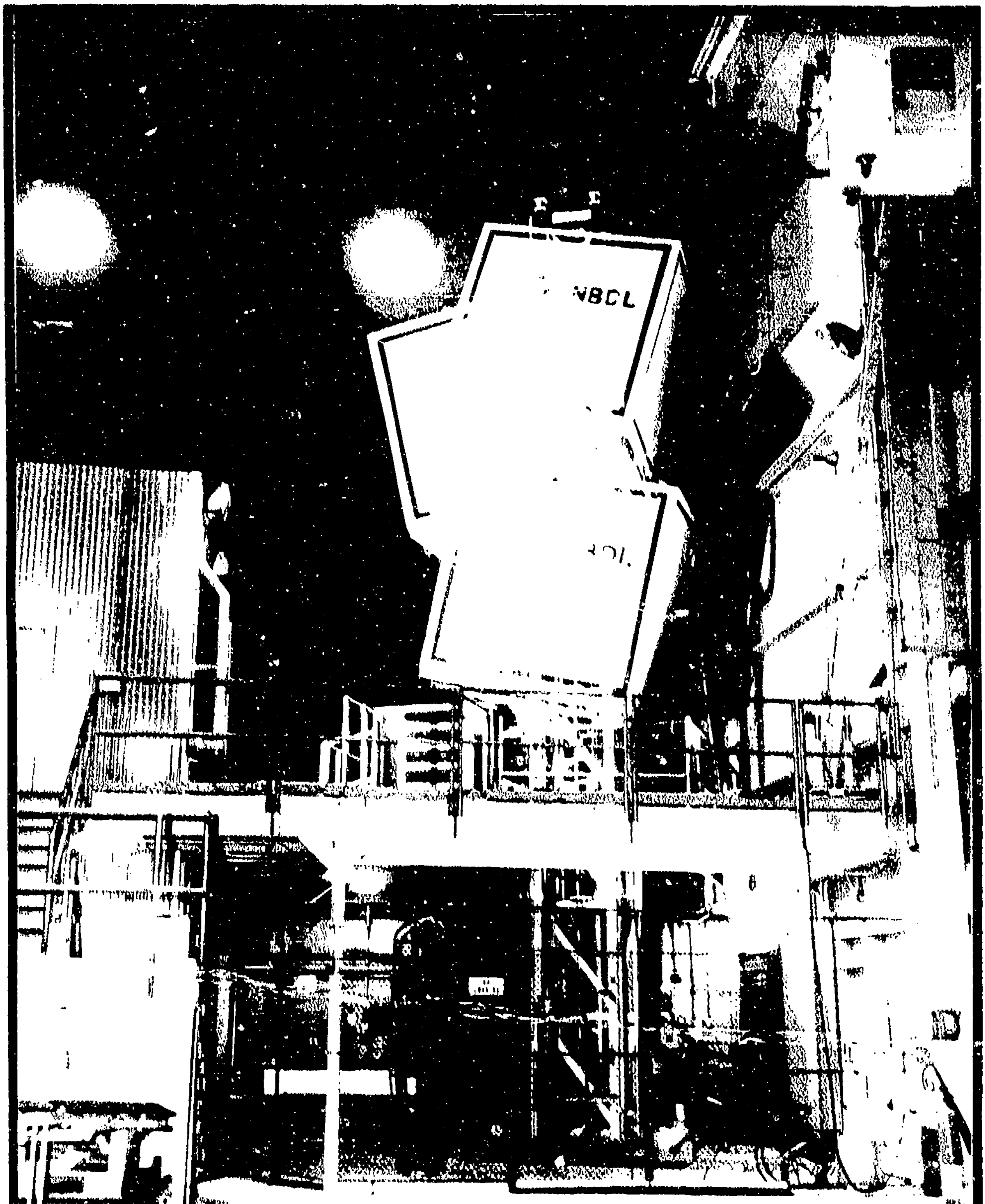
The flight profiles generated maintain hypergravity levels with minimal cross-couple coriolis effects. This is accomplished by high-velocity (Mach 0.75) flight in a coordinated turn at varying angles of bank to give gravitoinertial force fields varying from 1-2 G.



JOHNSVILLE CENTRIFUGE AT NAWC, WARMINSTER

The Johnsville Centrifuge is located at the Naval Air Weapons Center (NAWC) in Warminster, Pennsylvania. The centrifuge has a 50-ft radius, a rate of change of acceleration of 10 G/s, and can attain 40 G.

An altitude chamber 10 ft in diameter and 6 ft wide is mounted on the arm. This chamber is mounted inside a pair of gimbals that is powered to provide 360 deg of rotation of the inner gimbals rate of up to 30 rpm, while the outer gimbals rotated outward through a 90-deg arc.


NBCL

SHIP MOTION SIMULATOR (SMS) AT NBDL, NEW ORLEANS

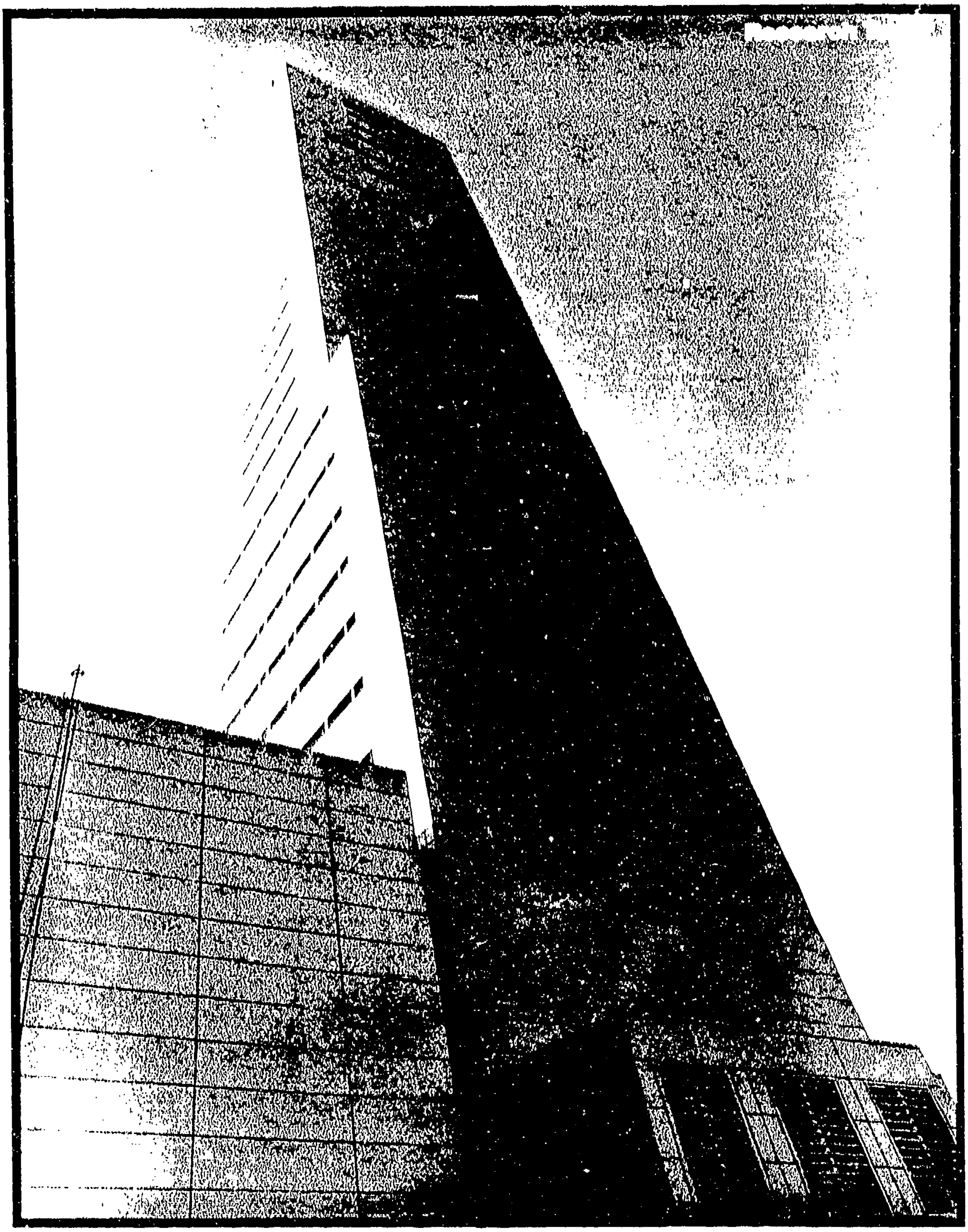
The Ship Motion Simulator (SMS) is located at the Naval Biodynamics Laboratory in New Orleans, Louisiana. The SMS has heave, pitch, and roll capability. A moving cabin is guided up and down in heave along a track attached to the 30-ft tower. As the cabin moves up and down in heave, it is also subject to roll and pitch motions produced by hydraulic-positioning systems. The moving cabin is 8 by 8 by 8 ft in height. Specifications and performance criteria are provided here.

HEAVE

Displacement	± 11 ft
Velocity	$> +18$ ft/s
Acceleration	$> +1.2$ g
	-0.9 g

PITCH AND ROLL

Displacement	$\pm$ 15 deg
Velocity	$\pm$ 25 deg/s
Acceleration	± 180 deg/s^2



OTIS RESEARCH TOWER

The Naval Aerospace Medical Research Laboratory (NAMRL) and Otis Elevator Company participate in a Cooperative Research and Development Agreement (CRDA).

The Otis Elevator Company Bristol Research Center sets the world's standard for elevator test facilities. The loftiest of Otis' 10 research towers worldwide, this $15 million facility, located in the Northeastern United States, is among the tallest in the industry.

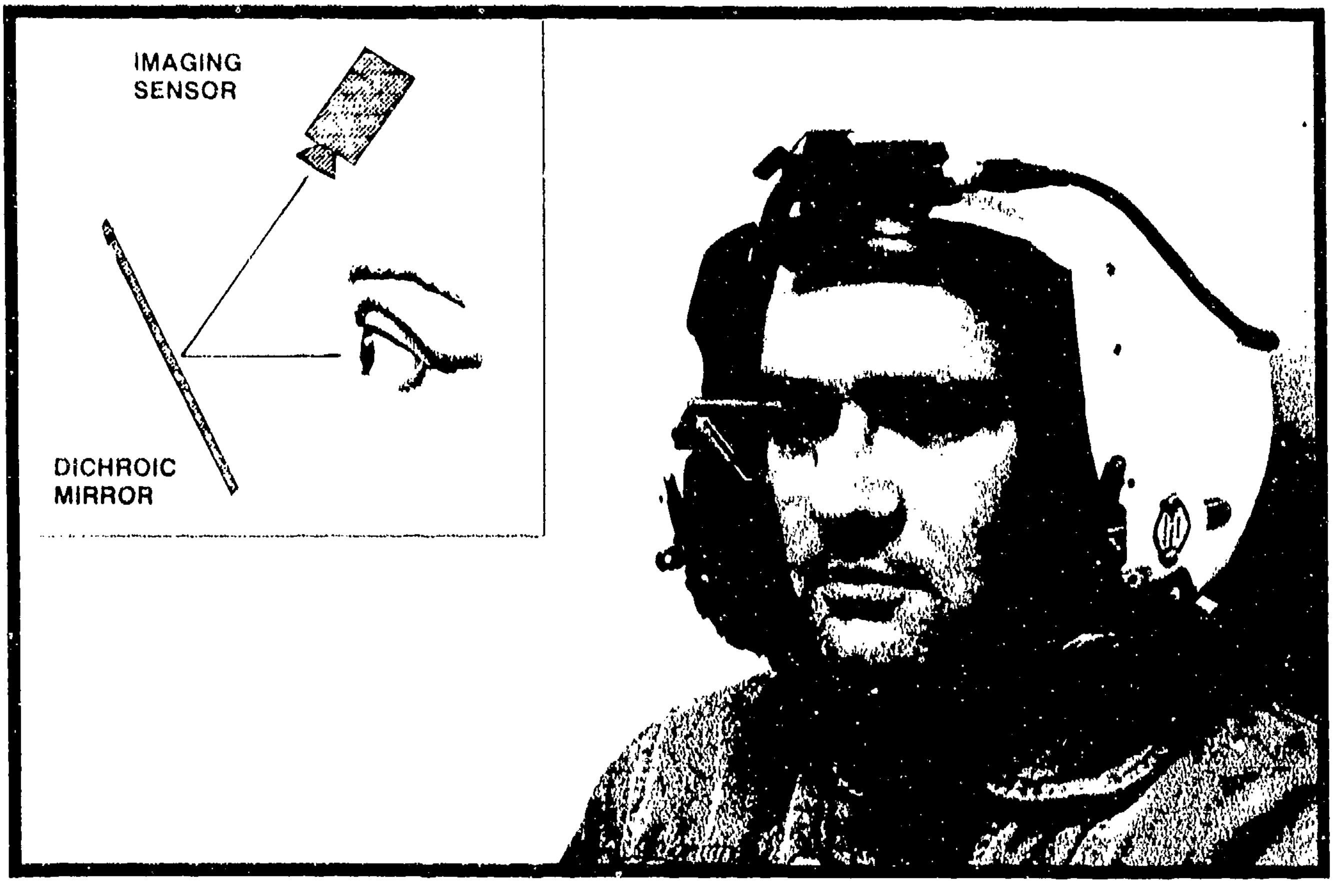
Soaring to a height of 29 stories, the tower's 131,274 ft^2 of space accommodates the testing of the most advanced high-rise elevator equipment. Its unique design provides maximum flexibility for research and testing at every phase of elevator and escalator development. Facilities include:

11 hoistways–

- 3 with 300-ft rises for testing highrise elevators
- 2 with 100-ft rises for testing midrise elevators
- 3 with 30-ft rises for testing lowrise elevators
- 2 with 100-ft rises for testing installation methods
- 1 heavy-duty elevator for servicing the tower

–and more

- large bay for testing escalators
- large, fully equipped machine room
- engineering work spaces
- machine shop


IMAGING
SENSOR
DICHROIC
MIRROR

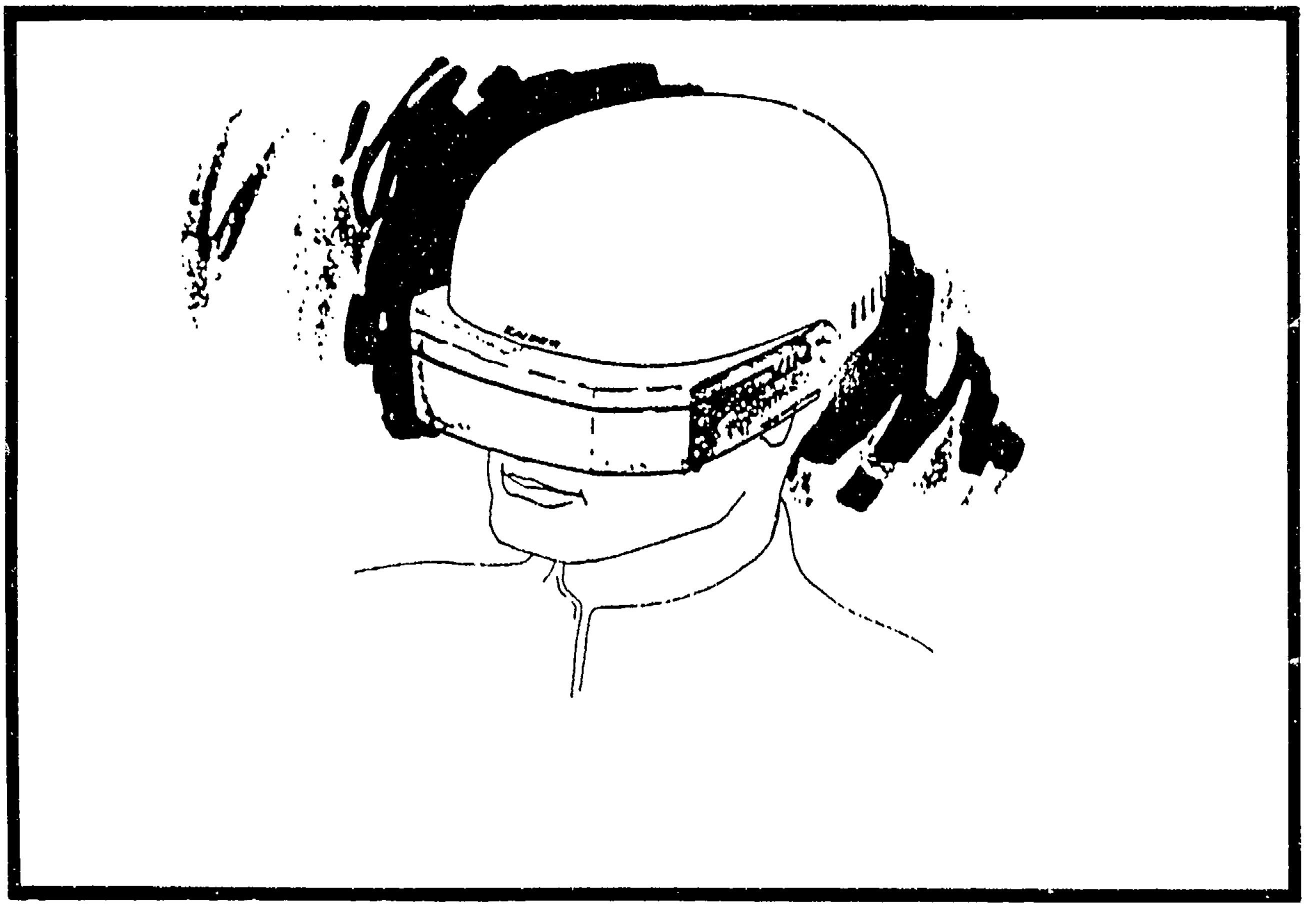
VISUAL DISPLAYS AND EYE-TRACKING EQUIPMENT

The visual and vestibular systems are intimately associated with the perceptual and motor responses of spatial orientation and motion sickness. The following devices are used in conjunction with the acceleration equipment of the previous section to examine the contribution of visual stimuli to spatial disorientation and motion sickness.

EYE-POSITION RECORDING

The reflex movements of the eyes in response to acceleration serve as a window into the operation of the vestibular system. To measure vertical and horizonal eye movements with more accuracy than the traditional electronystagmogram, we use a modified commercial system, ISCAN™

The ISCAN™ Pupil/Corneal Reflection Tracking System is a real-time digital image processor that tracks the center of a subject's pupil and a corneal reflection moving over the pupil. The difference between the subject's pupil position and corneal reflection position remains constant with small head movements, but changes with eye movement. The corneal reflection technique yields a linear representation of the subject's eye positions up to ±20 deg vertically and ±30 deg horizontally of the visual field with an accuracy of better than 1 deg.



VIM SPECIFICATIONS

MECHANICAL

Total Weight	≤2 lbs
Monocular FOV	45° V x 70° H Approximate

OPTICAL

Image Source	Active Matrix LCD
Angular Resolution	≤7.5 Min/Color Pixel Horizontal and Vertical
Color	RGB
Eye Relief	30 mm from corneal bulge Eyeglass-compatible
Display Image	VGA

ELECTRICAL

Interface	IBM PC compatible with SVGA interface; sound card and open slot required. Custom helmet drive electronics board included
Cable length	≤10 ft
Sound	Standard high-performance headsets included
Head Tracker	Compatible with commercial trackers

VIRTUAL REALITY DISPLAY

The Acceleration division has three Kaiser VIM™ head-mounted displays, each with a field of view of 45 deg vertical and 105 deg horizontal.

The head trackers used include sound source, mechanical, and infrared.

Head Trackers

Sound Source

The Naval Aerospace Medical Research Laboratory has two model GP8-3D Sonic digitizers. The GP8-3D Sonic digitizer consists of digitizing sound emitters, 4 sensors, the control unit containing the electronics and connector sockets, and the multiplexer unit with up to 16 sound-emitter channels. To determine distances, the GP8-3D uses the transit time between the sensors and the sound emitters. A counter measures the time it takes the sound to reach the sensors from the sound emitter. Using the known speed of sound, the appropriate distances can be calculated. The resolution is 0.01 cms or 0.01 inches, and the active volume is a 6-ft cube.

Mechanical

The Physical Headtracker is a sophisticated and inexpensive 6D tracking system that converts position and orientation information into computer-readable form.

The Physical Headtracker calculates head/object position with six degrees of freedom by use of a lightweight, multiple-jointed arm. Sensors mounted on the arm measure the angles of the joints. The microprocessor-based control unit uses these angles to compute position-orientation information in a user-selectable coordinate system, which is then transmitted to the host computer. Resolution is 0.025 inches and 0.3 deg.

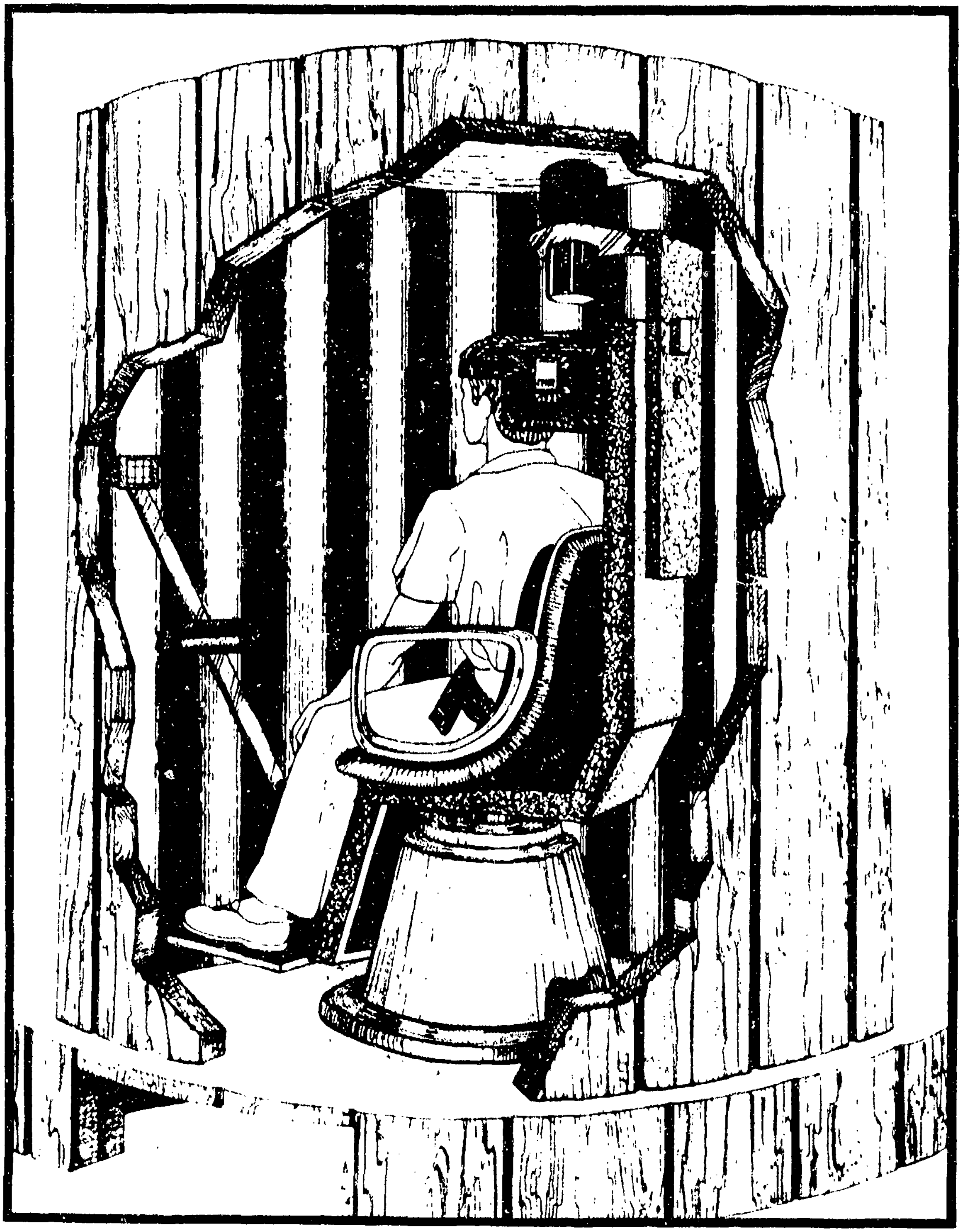
Infrared

The infrared headtracker consists of an infrared source with a helmet mounting fixture, one source electronics, one sensor, one sensor electronics, and a digital signal processor (DSP) The source and the sensor are connected to the source and sensor electronics, respectively. The source and sensor electronics are connected to the DSP.

The DSP interfaces with the host computer VME bus.

The headtracker provides the position coordinates (x, y, z) of the source origin in the sensor's coordinate system as well as the Euler attitude angles (yaw, pitch, roll) of the source orientation (attitude) relative to the sensor coordinates system. The position is reported in centimeters, and the angles are in degrees.

The data resolution is less than 0.1 inch RMS for position and 0.3 deg RMS for attitude angles at a nominal 13-inch source-to-sensor separation.



OPTOKINETIC DISPLAYS

In addition to the optokinetic displays presented by the VR devices, there are a variety of full-field-of-view optokinetic stimuli available. The visual vection-vestibular device described below incorporates a horizontal motion optokinetic stimuli with an acceleration chair. A more portable and mobile display consists of a 1-meter diameter hemisphere onto which vertical or horizontal optokinetic displays are projected.

Visual Vection Vestibular Device

The Rotary chair has a dc torque motor drive capable of a top speed of 300 deg/s and a maximum acceleration of greater than 150 deg/s^2. The nominal peak torque of the drive is 30 ft-lbs.

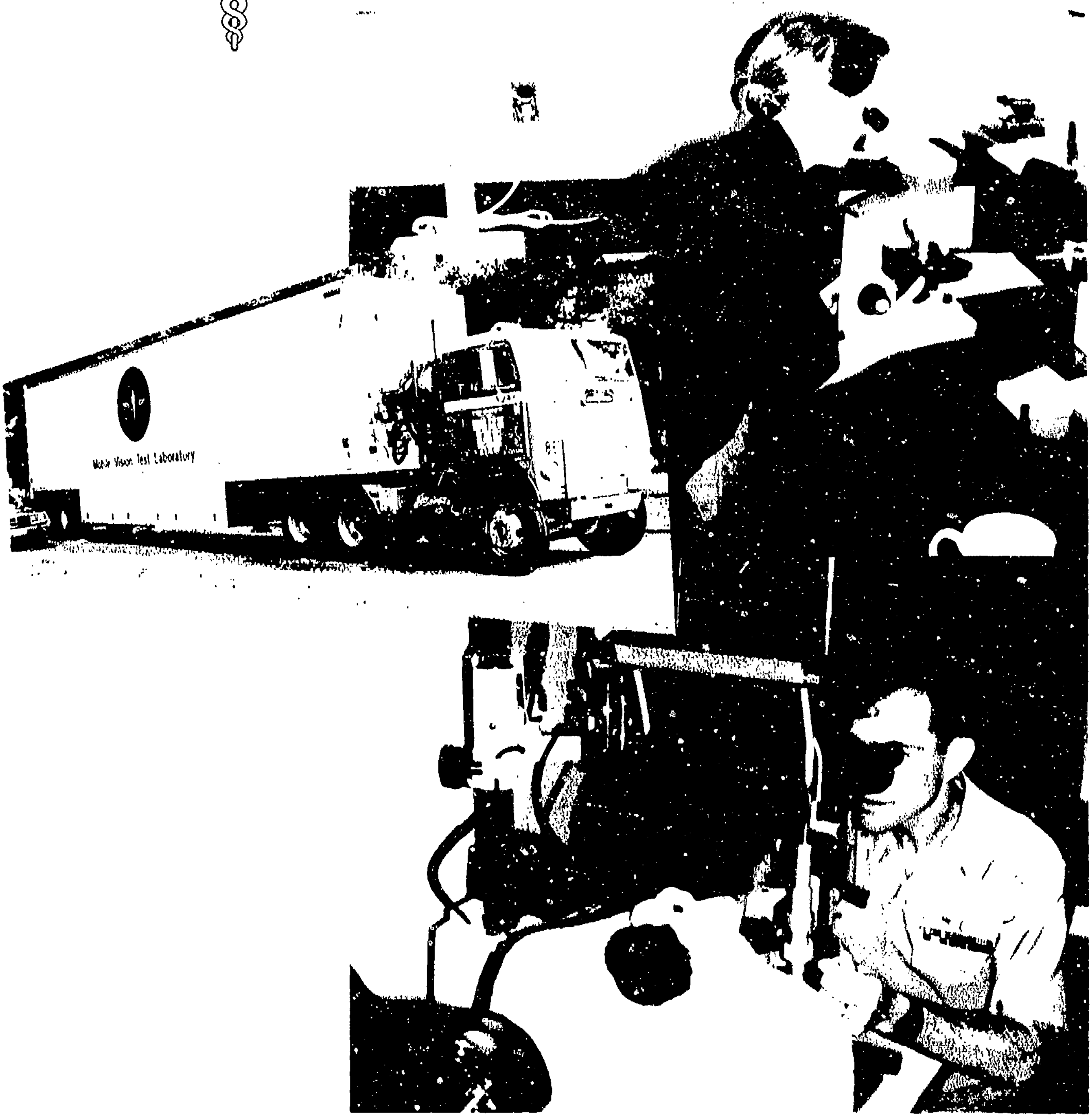
The chair is enclosed in an 8-ft diameter, white seamless visual surround with entrance from beneath the device. Attached to the chair above the subject is the optokinetic generator, which projects moving displays in the subject's horizontal plane. The chair and the OKN stimulator are closed-loop velocity servo systems independently programmable, capable of matching the performance of one to the other.

EXPERIMENTAL SUBJECTS

The Naval Aerospace Medical Research Laboratory is most fortunate to have access to a large pool of aircrew eager to volunteer as subjects. Approximately 1000 recent college graduates report annually to Pensacola for pilot and naval flight officer training programs. These well-educated, highly motivated, young men and women have all passed a stringent flight physical prior to acceptance into the flight program. All types of pilots are available (jet, helicopter, and propeller communities) at levels of experience varying from preflight through instructor and ages 22 through 45. With the recent demographic changes in the Navy, women and minorities are well represented.

In addition, NAMRL has a long relationship with schools for the deaf and clinicians having access to individuals without functioning inner ears (i.e., labyrinth defective). Such individuals are valuable to identify the relative contribution the vestibular system makes to the orientation processes and to serve as standards by which we evaluate tests of vestibular function.

Another clinical group of importance to our laboratory is the clinical aircrew referrals sent by NAMI and the United States Army from Ft. Rucker, Alabama. The Navy has a long history of cooperative vestibular research with the United States Army Aeromedical Research Laboratory in Ft. Rucker based primarily on a mutual interest in helicopter disorientation.


Mobile Vision Test Laboratory

MEDICAL SUPPORT

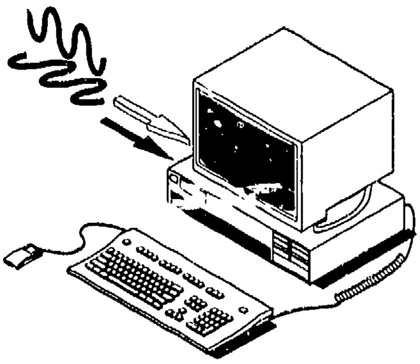
Presently, NAMRL has three Navy flight surgeons on the staff who serve as medical monitors for experiments. An adjacent clinic provides additional support as does the NAMI. This includes specialists in neurology, internal medicine, ear nose and throat, and ophthalmology.

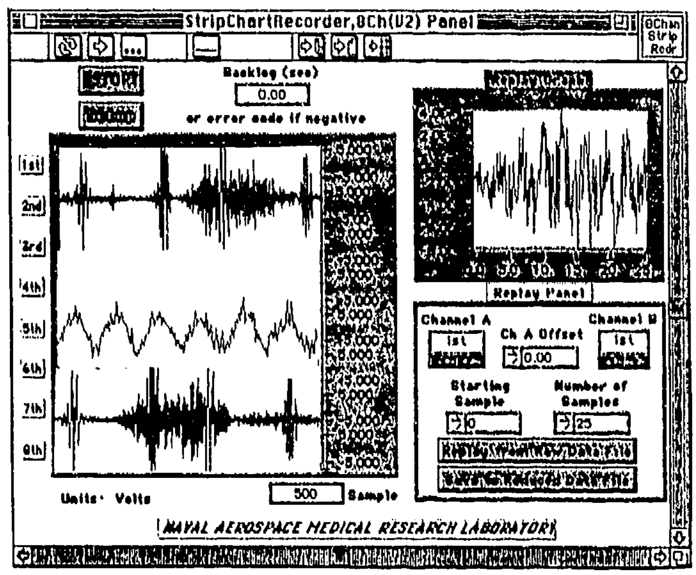
Subjects who volunteer for experiments with "greater than minimal risk" protocols and who are not in current flight status receive a standard Navy flight physical exam and biochemistry workup from NAMI.

TECHNICAL SUPPORT

The Acceleration division engineering staff is responsible for design, modification, maintenance, and training of operators for all acceleration devices. Typically considerable modification and setup time are required to meet the specifications set by each investigator.

If the modifications exceed the capability of our local machine shop or require high-G impact testing to meet stringent protection of human subject regulations, we use the unique construction and impact testing facilities of our sister research laboratory, the Naval Biodynamics Laboratory in New Orleans, Louisiana.





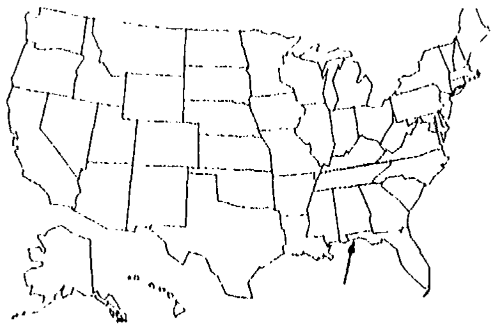
DATA ACQUISITION

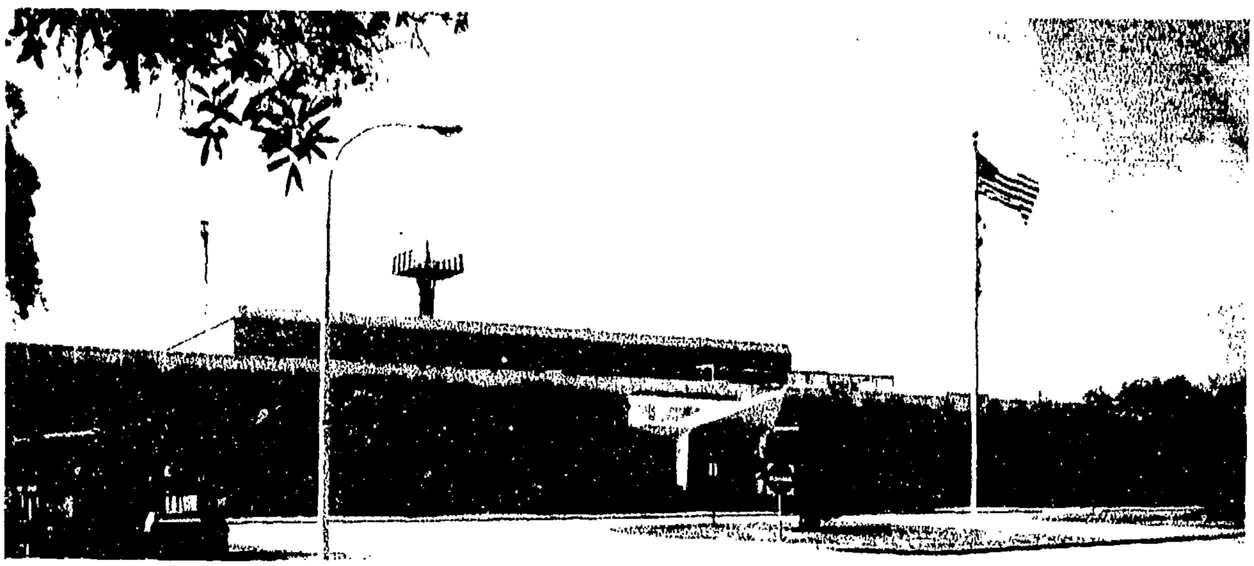
DATA ACQUISITION

The Naval Aerospace Medical Research Laboratory acceleration division has the following data acquisition equipment available for recording of physiological signals (eye movements, blood pressure, etc.) and measurement signals (head-fixed accelerometers, device tachometers, etc.).

- Two Macintosh Quandra 950 computers equipped with National Instruments (NI) multifunction analog and digital I/O boards. LabVIEW 2 data acquisition software is used for data logging to disk and real-time display. NI direct memory access boards are also used for high sampling data applications.
- Macintosh IIci computer equipped with a GW Instruments multifunction analog and digital I/O board. SuperScope data acquisition software is used for data logging to disk and real-time display.
- TEAC PCM 8-channel analog instrumentation magnetic tape recorder.
- Gould TA4000 8-channel strip chart recorder.
- Panasonic AG 1830 ProLine S-VHS VCRs for recording video signals.

White sandy beaches
Moderate temperatures
Historical districts
Cradle of naval aviation
Home of the Blue Angels
Leading edge of naval medical research





Naval Aerospace Medical Research Laboratory

PENSACOLA, FLORIDA AND THE NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY

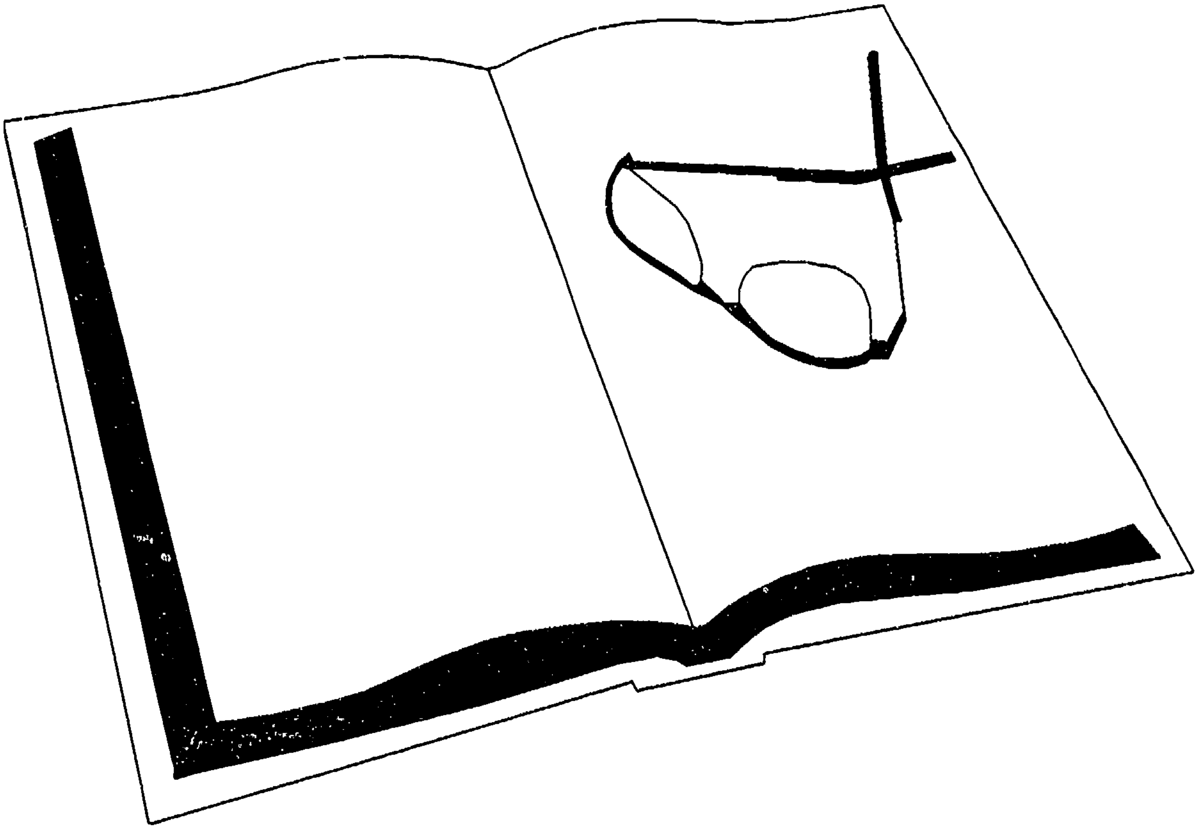
Pensacola is well-known as the cradle of naval aviation. Because of its location in Pensacola, the Naval Aerospace Medical Research Laboratory (NAMRL) is uniquely positioned to conduct research in aerospace medicine, aerospace physiology, and aviation psychology with special emphasis on research requiring subjects who are in various stages of aviation training.

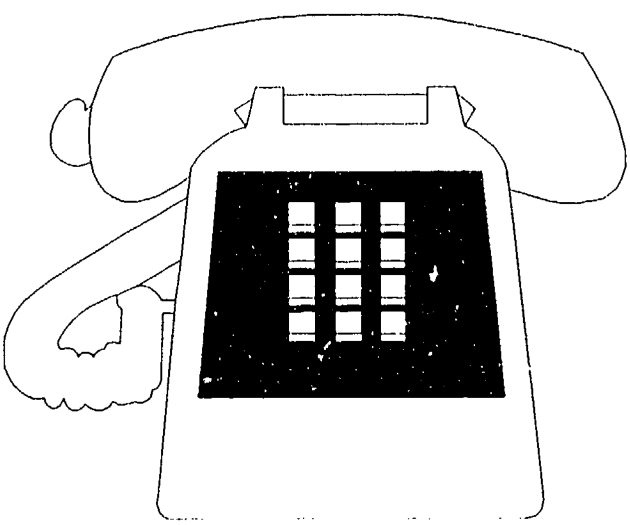
Pensacola's comfortable climate, gulf cost proximity, and low cost of living make it an attractive location. Many scientists consider these factors so important that they have stated they would not relocate elsewhere.

There are a variety of scientific disciplines at NAMRL that include specialists in psychology, physiology, neuroscience, biophysics, biomedical engineering, optics, audiology, electrical engineering, mathematics, biology, and ophthalmology. They are supported by experienced biological and physical science technicians, capable Navy hospital corpsmen, and a skilled administrative, technical, and fiscal staff.

The Laboratory has Memoranda of Understanding with local universities. Graduate students from the engineering departments at Massachusetts Institute of Technology (MIT) and Tulane University have been involved in recent projects. We interact with their staffs, and actively seek co-op students and thus, "grow our own" future researchers. The multidisciplinary interaction and strong synergism between the facilities are extremely important as naval aviation research problems become more and more complex with advancing technology.

Our Memorandum of Understanding with NASA played a significant role in early space flight. Laboratory scientists developed life-support systems and monitored cardiovascular activity for the first primate (a squirrel monkey named Miss Baker) to survive a space launch. Later, the original seven Mercury astronauts trained on the laboratory's disorientation devices and participated in acceleration research. Studies of sensorimotor adaptation to weightlessness and other unusual acceleration environments, particularly constant speed rotation, are the main source of data used for decisions concerning the feasibility of artificial gravity in prolonged space missions. Laboratory scientists currently make up part of the planning team for proposed manned missions to Mars. In addition, the laboratory has recently duplicated parts of the space shuttle profile to better assess the vestibular effects experienced by the crew.





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The wide variety of unique devices together with the scientists and technicians who operate them have enabled the Naval Aerospace Medical Research Laboratory (NAMRL) to develop an international reputation as a center of excellence in vestibular research and the dynamics of spatial orientation, and for training outstanding scientists who are engaged in basic research worldwide.

This document contains a brief description of the man-rated acceleration research facilities of the United States Navy.

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